Coastal Forest Monitoring Protocol, Cape Cod National Seashore

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Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.00	1981	Dr. William Patternson (UMASS)	Initial draft	Assess fire regimes in primary CACO forest types
1.01	1995	Una Chokkalingam (UMASS)	No changes	Resurvey of Patternson sites to analyze temporal change
1.02	1999	Nels Barett (NPS, CACO)	Recommends major change to sampling method	Obtain more quantitative data
2.00	2001	Andy Hubbard (NPS, CACO)	Adopts new sampling method and revises protocol text to reflect	Conform to more current forest monitoring methods
2.01	2002/2003	Stephen Smith (NPS, CACO)	Expands monitoring network Proposes additional monitoring parameters	Increase spatial scale of sampling and collect more types of data

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Background and Objectives

Background and History

Although Cape Cod National Seashore (CACO) is perhaps best known for its shoreline scenery, the interior forests and woodlands have become the most prominent feature of this coastal landscape. In the period before European settlement, Cape Cod was covered largely by pine-oak forests, interspersed with smaller areas of hickory (insert *Scientific name*), beech (*Fagus grandifolia*), red maple (*Acer rubrum*), and birch (insert *Scientific name*) (Motzkin et al. 2002). In the 18th and 19th centuries, much of Cape Cod consisted of open heathlands and grasslands created and maintained primarily by the agricultural practices of early settlers that included cutting, grazing, and burning (Eberhardt 2001, Eberhardt et al. 2003). The cessation of these activities by the mid-1800s allowed trees to re-invade the landscape (Patterson et al. 1983, Motzkin et al. 2002, Parshall et al. 2003), and forests now occupy the largest land-surface area and biovolume of any vegetation community (Figure 1).

Currently, the dominant tree species of CACO are pitch pine (*Pinus rigida*), black oak (*Quercus velutina*), and white oak (*Quercus alba*). Various mixtures of these comprise most of the forest habitat, which is broken up by smaller areas of black locust (*Robinia pseudoacacia*), red maple and beech. *P. rigida* is a drought-tolerant, fire-adapted species that thrives on the well-drained, acidic soils of CACO and is increasing in abundance in areas of former heathland (Barron 2004). In many places, however, *P. rigida* has declined in relative abundance, giving way to the shade-tolerant and longer-lived *Q. velutina* and *Q. alba*. Although *Quercus* spp. have sporadically been defoliated by gypsy moths over the latter half of the 1900s, the successional sequence of *P. rigida* to *Q. velutina* to *Q. alba* now continues relatively uninterrupted across large portions of upland habitat, particularly on xeric, sandy soils—a process that is encouraged by active fire suppression (Patterson 1983, Chokkalingam 1995, Barron 2004). In more mesic soils or in areas
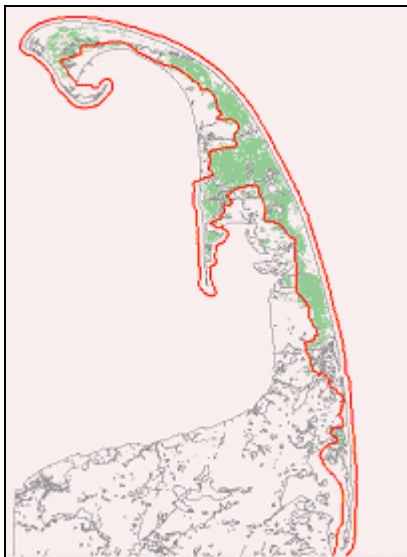
Figure 1. Map depicting 2000 aerial cover of forest/woodland habitat (green-shaded area) within CACO (red boundary).

that are seasonally flooded, *A. rubrum* and, to a much lesser extent, Atlantic white cedar (*Chamacyparis thyoides*) are abundant. Stands of *R. pseudacacia*, most of which were planted by humans, exist as scattered, isolated patches throughout the middle and southern portion of CACO, whereas *F. grandifolia* predominates within a single, unfragmented stand of mature forest at the northern tip of the peninsula.

In general, the forests and woodlands of CACO are the product of both cultural and natural influences. The independent and interactive effects of human history and the coastal environment have resulted in a unique mosaic of forest types, each with the potential to follow a different trajectory of change. Monitoring and understanding this change has become an important priority for the Seashore.

Rationale for Monitoring Coastal Forest Habitat at CACO

Forest communities within CACO are found over a broad range of topographic, hydrologic, and geologic conditions and provide an expansive habitat for a large number of flora and fauna. As such, forests may serve as an important indicator of the ecological health of not only CACO, but Cape Cod itself. Both natural and anthropogenic factors influence the health of forests. Chronic and episodic climatological factors, fire, fire suppression, disease, invasive species, insects, succession, fragmentation by development, acid deposition, ultraviolet radiation, global warming, and air pollution have been identified as having the potential to significantly alter this diverse habitat (Roman et al. 1999). Such realized and potential threats necessitate a comprehensive system of response monitoring. To objectively assess spatial and temporal variation in forest ecosystems in a manner that is scientifically robust, it is imperative that a standard protocol for collecting and processing information be followed. This ensures that data maintain a high level of integrity that is vital to drawing any conclusions through analytical inquiry. However, it should be mentioned that it is difficult, if not impossible, to predict what additional or new kinds of information may be needed in the future. Thus, the protocol may periodically need some form of modification to fit these needs, while still maintaining enough of its original form to make comparisons to the oldest datasets. To guide this process, critical reviews of the protocol should be conducted along the way.

This document proposes a methodology for implementing a system of monitoring designed to provide high-quality information on the status of forest resources across CACO. While the protocol itself should serve as the primary tool with which to assess structural and functional changes in these communities, available environmental datasets on potentially important abiotic factors (e.g., elevation, precipitation, air quality, soil properties) can help to elucidate underlying mechanisms of change and, subsequently, guide the management of the resource. It is expected that these kinds of analyses will also assist investigators studying other biological systems. For instance, certain wildlife respond to forest habitat suitability as defined by taxonomic composition, productivity, and/or reproductive output (Fuller and DeStefano 2003, Cook and Boland 2004). Similarly, forest processes are highly relevant to the monitoring of adjacent habitats, such as heathlands and grasslands, which are slowly being lost through succession (Motzkin et al. 2002).

History of Protocol Development

CACO is part of the Northeast Coastal and Barrier I&M Network. It should be noted that the other parks in the Northeast region of the U.S. use protocols that are similar in some respects but different in others, to monitor forest vegetation. The major similarity between CACOs protocol and those within the Northeast Temperate Network (NETN), for example, lies in the concept of fixed-, rather than variable-area sampling. In this regard, CACO chose a protocol in 1999, well before any of the NETN protocols were in place that was based on fixed-area sampling and developed by Peet et al. (1998). Overall, this was considered to be a better way to collect data in a quantitative fashion. Sampling sites were chosen so that there was overlap with Dr. William Patterson' (University of Massachusetts, Amherst) original (1981) variable-area sampling sites in order to be able to analyze decades-long changes.

Patterson established 21 sampling sites in forest habitat within the boundaries of CACO. The primary objective of this study was to collect data on forest structure and composition for modeling fire regimes (Patterson et al. 1983). The sites themselves were defined by a network of rebar stakes (hereafter known as "fire stakes") representing points at which data were collected. The number and arrangement of stakes varied among sites and were based on subjective determinations of stand boundaries as inferred by various structural and compositional commonalities (Patterson et al.1983) (also see Appendix B for layout of stakes).

In characterizing the sites, trees were sampled in two ways: At each fire stake, an angle gauge ("Cruz-all" type) was used to estimate basal area and tree densities, which yields data within circular areas of variable-radius depending on tree size and distance away from the sample point. In addition, tree cover was recorded within 20×20-m subjectively placed relevé plots (Figure 2), which varied in number according to stand size. Unfortunately, the boundaries of the relevé plots were not marked with permanent monuments. Since GPS technology did not exist at the time, they could not be relocated with any reasonable accuracy. Estimates of percent cover of near-ground (i.e., shrubs, saplings between 0.5 and 2 m in height) and ground (<0.5 m in height) vegetation were recorded as ordinal ranks (see scale in SOP#5) in 1-m^2 fixed-area circular plots (the center of each plot being the fire stakes).

In 1991, Unna Chokkalingam (Dr. Patterson's graduate student) re-located and re-surveyed 13 of the original fire-stake arrays to analyze changes over the previous decade (Chokkalingam 1995). As in 1981, trees were sampled in variable-radius plots. Shrub vegetation, however, was assessed in a different manner, by enumerating stems within 4-m^2 circular plots centered on each stake. Similar to 1981, herbaceous cover was recorded within 1-m^2 circular plots.
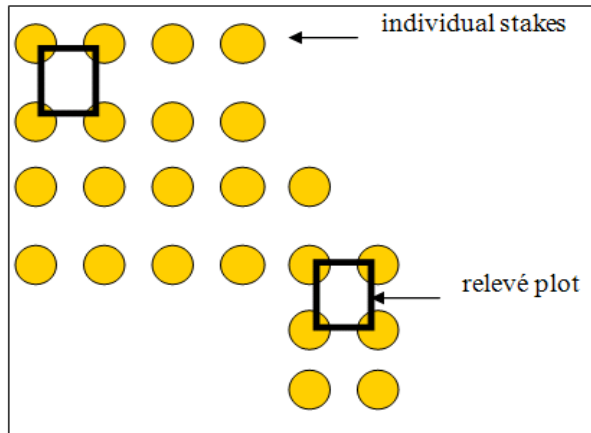
Figure 2. Example of the original relevé and point-sampling plan at a sampling site.

In 2002-2003, the 13 sites surveyed in 1981 (Patterson et al. 1983) and 1991 (Chokkalingam 1995) were revisited and sampled by both the original method (variable-radius point-sampling) and a new method that used a fixed-area (modular) design (Barrett 1999, Hubbard 2001). Sampling by the two methods provided an opportunity for quantitative comparisons using regression analysis (see Appendix A), and qualitatively where the variates are not directly comparable. Sites that could not be relocated, or that had since been dramatically altered, were not sampled (see Appendix B). Near-ground (shrub) vegetation was assessed in a different way than in 1981 and 1991. A 5-m field tape was stretched along a 305º bearing (randomly determined) out from each stake, and relative cover (percent of the line) by shrub species recorded (Hubbard 2001). Although the line-intercept method is an acceptable way to describe vegetation, the consequence of changing methods is that comparisons between the different time periods are compromised. Finally, square 2×2-m plots (centered on the rebar) were used for visual estimation of ground cover (<0.5 m) at each stake.

Objectives
i) Management objectives: CACO has not yet developed any specific management objectives, but is currently working on linking forest cover with heathland and cultural vista management objectives. The general purpose of the latter is to maintain open landscapes by suppressing the succession of grasslands and shrublands to woodlands and forest. While methods are still under development, it is expected that various combinations of cutting and fire will be used to accomplish this task.

iii) Monitoring objectives: CACO's principal monitoring objective is to document the spatial and temporal components of change within specific forest community types. The sampling design seeks to provide high-quality quantitative data on forest structure, including the understory vegetation. We also wish to examine compositional variability and change (i.e., relative species abundances). In particular, rates of successional change are of high value, in that it provides a timescale for the disappearance of open landscapes, and, vice versa, the frequency with which cutting and burning regimes need to be applied.

Because this protocol was adapted from a previous monitoring design (Patterson et al. 1983), it is perhaps better suited to analyze changes occurring within different forest community types, rather than park-wide, although the latter can still be done and provide useful information. In a statistical context, it would be desirable to be able to detect a 20% change in important forest attributes (tree density, basal area, etc.) for each different forest type with an 80% level of certainty.

Sampling Design

Rationale for the New Sampling Design

Although useful for rapid inventories of forest structure, the variable-radius plot method has some limitations for repeated, long-term sampling. Namely, the area surveyed is dependent upon stand characteristics, which gives reasonable estimates of basal area, but poor estimates of tree densities and diameter distributions (Larson 1999, Sparks and Masters 2002). By contrast, fixed-area plots allow for precise tracking of tree growth and composition within an unchanging sampling area (Bakker et al. 1996, Herben 1996).

The fixed-area plots originally recommended by Barrett (1999) and adopted by Hubbard in 2001 essentially follow the design of Peet et al. (1998). In this approach, four 10×10-m (0.01 ha) replicate square "modules" are laid out at each forest site, with the typical arrangement being a cluster of adjacent modules in a 20×20-m (400-m^2) area equaling the size of the original relevés (Figure 3). At sites with a narrow band of trees or certain geomorphic or anthropogenic features (cliff, road, etc.), the modules were arranged in a linear fashion, or with variable spacing between modules. Within the modules, smaller-sized plots are nested in the corners for understory sampling (Figure 3). This general plot layout, or similar versions of it, have been adopted by other national parks (Densmore et al. 1997, Jenkins 2001, Bowersox et al. 2004), Long Term Ecological Research sites (Foster and Aber 2003), and the USGS/NPS Vegetation Mapping Program (TNC and ENSR 1994). In fact, the design is currently in wide use around the world (Allen 1993, Stohlgren et al. 1995, Acker et al. 1998, Roberts-Pichette and Gillespie 1999, Williams et al. 1999, Campbell et al. 2002, Ipor et al. 2002).

One set of four module-based plots was located within each original stand delineated by Patterson. Specific locations for the module-based plots within the larger network of fire stakes were selected based on the fire stake(s) that appeared (subjectively) to best represent the general character of the stand (E. Barron, title, affiliation, pers. comm., date). While the modules represent varying proportions of these stands and may not adequately describe the whole stand
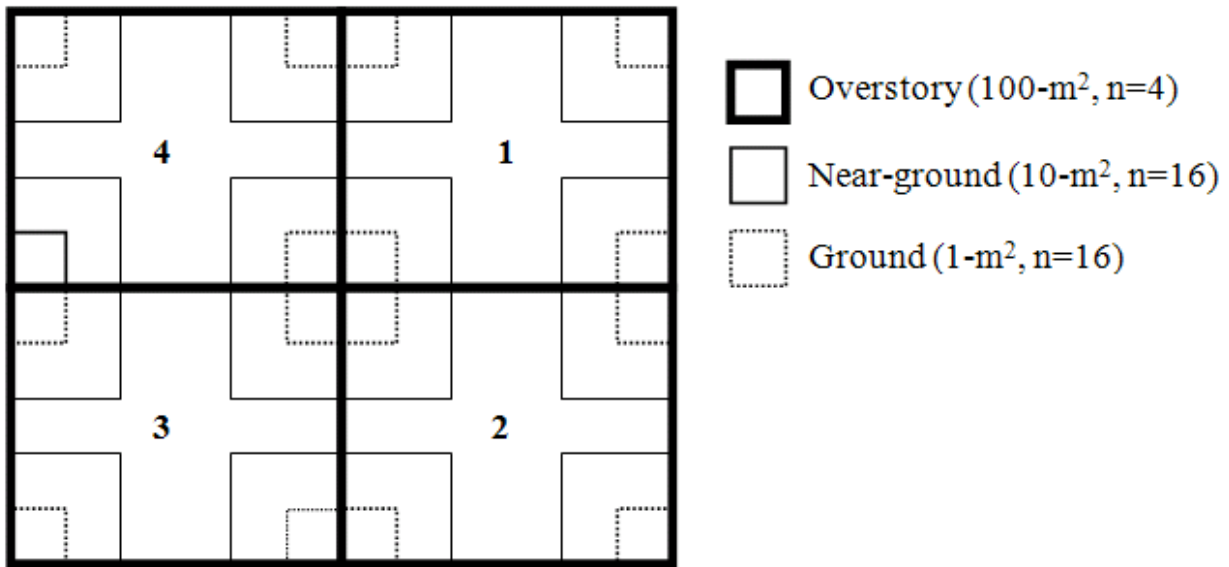
Figure 3. Schematic of the four 100-m^2 module system with nested subplots for estimating near-ground (shrub) and ground (herb) cover.

that was originally selected for point sampling, the most important goal is to characterize changes within that specific parcel of land through time. However, for consistency in conducting the monitoring, we felt it important that all the new modules be identical in spatial scale rather than having different sizes based on overall stand size. This is more desirable in a statistical sense as well.

The modules were oriented so that a stake represented a corner of one or, in the case of the clustered pattern, several modules with one or several other fire stakes generally in close proximity (Figure 4). How were modules located within the additional 24 stands?
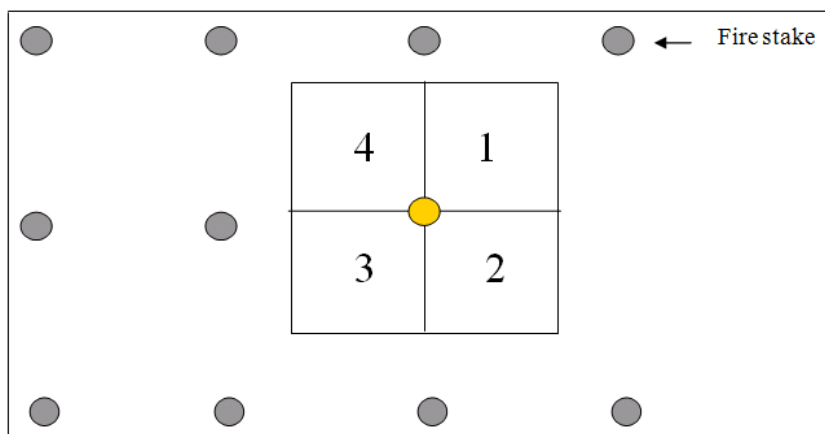
Figure 4. Orientation of modules in relation to variable-radius plot sampling locations (fire stakes).

Procedures for Fixed-radius Sampling

In fixed-radius plot sampling, all trees >2 m within each module (n=4) are tallied by species and measured for diameter at breast height (DBH). Shrub cover by species is estimated within 10-m^2 (3.3×3.3-m) nested plots (n=16). Herbaceous cover by species is estimated within 1-m^2 (1×1-m) nested plots (n=16). The different plot sizes for each stratum were chosen primarily to facilitate accurate visual assessments of cover. The size and stature of shrub vs. herbaceous vegetation differ in a way that makes it difficult to see each stratum in its entirety in the larger plots.

Revisions to Module Design and Specifications

During the summer of 2002, steps were taken to remove potential error in re-establishing plots, which were previously delineated in 2001 using only one permanent marker and compass bearings. To ensure that plots encompass the exact same area every time they are sampled, the corners of each module were marked with 1-in diameter PVC stakes inserted into the ground to a height of ~1–2 ft. (note: if there is a fire in the area, the aboveground portion will usually melt into an amorphous mass that is still recognizable as PVC). In addition to establishing permanent plot markers, aluminum tags, each with a unique ID number, were nailed to the main trunk of all trees >2 m in height. Apart from being able to track the growth of individual trees, this had the added benefit of marking a reference point for DBH measurement locations. Tagging trees also provided redundancy in terms of delineating plot boundaries (i.e., all trees with a tag are in the plot and vice versa) and locating sites. Because it was impossible to match 2001 tree data with the new tags, all trees within the plots were sampled again so that each tree-related datum corresponded with an ID number.

Revisions to Spatial Scales and Frequency

In 2001, cover estimates were done for near-ground and ground species in all plot sizes (i.e., 1 m^2, 10 m^2, and 100 m^2) in every module. However, all species recorded in the smaller plots would, theoretically, also be contained within the larger ones. Presumably, this was done to calculate species-area curves. However, the experience of the field crews suggests that it is extremely difficult to accurately determine cover for either layer within the entire area of each 100-m^2 module. Moreover, the 1-m^2 plots are too small for reliable estimates of near-ground (shrub) cover while the 10-m^2 plots are too large for ground (herbaceous) cover. Thus, in 2002, estimates of cover for near-ground vegetation (vegetation between 0.5–2m in height) were limited to four 10-m^2 (3.3×3.3-m) plots in each module (total of 16 per site), while ground cover (vegetation <0.5 m) was assessed in four 1-m^2 plots in each module (total of 16 per site). Restricting the data collection to these smaller plot sizes may increase the probability of missing rarer species, although any individuals not occurring within the nested plots but present within the boundaries of the larger modules were recorded anyway. Regardless, the main objective of this protocol is not to analyze population dynamics of rare species in the understory; to properly address such concerns, a separate protocol is necessary. Rather, it is to detect trends in the overall structure and composition of forests, with the overstory vegetation being the main component of interest.

Expansion of Spatial Sampling

The 21 original site locations classified and selected by Patterson et al. (1981) were part of a study to characterize fire regimes in three community types - pine, pine-oak, and oak habitat. With the exception of 6 sites that could not be re-located or were heavily disturbed by human activity since 1981, these locations (15 remaining) were retained as part of the network of fixed-

area plots, as they provide a valuable long-term (>20-yr) record of forest population dynamics. Although they represent the most common types of forest habitat across CACO, they are somewhat limited from both a geographic and floristic standpoint. With respect to the latter, the sites can be broadly characterized as pitch pine-heathland (n=2), pitch pine (n=4), mixed pitch pine-black and white oak (n=7), black and white oak (n=1), and beech (n=1). In 2002, an additional 24 sites were established to broaden the spatial scope of monitoring, increase replication of under-represented types (e.g., oak, beech), and incorporate other forest types (e.g., red maple, black locust, Atlantic white cedar). These additional sites were located by generating random points (using the Alaska Pak tool for Arcview™ ver. 3.2) within specific forest-type polygons delineated on the 1991 CACO vegetation map.

Additions and Revisions to the Protocol

In an effort to continue improving and refining the protocol, the following additional parameters are undergoing evaluation for possible inclusion in the methods. However, it is expected that several samplings will be necessary for any rigorous assessments to be made.

i) Sampling all trees – In previous surveys, only trees with DBHs ≥10 cm were measured and counted. In 2002 and 2003, all trees above 2 m in height were tagged, measured, and counted so that the entire population could be followed through time.

ii) A range of 0.5–2 m in height was originally used as the criteria for defining the shrub stratum. However, shrub species in the understory of Red Maple, Atlantic White Cedar, and Black Locust forest types commonly exceed the upper limit. Yet these taxa (e.g., *Viburnum dentatum*, *Lonicera morrowii*, *Ilex glabra*) cannot properly be considered part of the overstory, since they will never grow as tall as the species that make up the canopy and do not evolve into true forest types. Accordingly, this layer will sometimes include individuals that are greater than 2 m in height but will not become canopy members (they are generally <4 m).

iii) Canopy cover – Overstory canopies are an important component of forest architecture which, by virtue of light attenuation, influence the growth and character of understory vegetation (Pagès et al. 2003). From a wildlife perspective, canopies offer protection from predators and influence the living conditions for a variety of fauna (Werner and Glennemeier 1999). Canopy cover is being assessed through analysis of hemispherical digital images (SOP#5).

iv) Maximum tree height – the height of the tallest tree in each module is estimated visually with the aid of a 2-m long reference pole that is stood on its end next to the bole of the tree. This method was chosen as an alternative to using a clinometer, since there is more flexibility in positioning oneself to see the top of the tree. In some stands, where tree densities are very high, it is extremely difficult to obtain clinometer measurements from a single point at a reasonable distance away from the tree. Furthermore, no additional measurements are needed to adjust for slopes and angled terrain. Finally, ocular determinations of tree heights have proven reliable in other studies (Deadman and Goulding 1978, Bechtold et al. 1998) and the data can always be transformed to an ordinal scale for statistical analysis.

v) Seedling counts – Information on the relative abundance and growth of tree seedings/saplings is useful in understanding potential trajectories of change through succession and the success or failure of recruitment. In 2002, the stems of all tree species <2 m in height were counted in each

module and tallied by species. Stems greater than this height were not counted since these were all tagged as overstory trees.

vi) Tree coring – Nine trees from each site, representing three different DBH size classes, will be cored and aged by counting tree rings. In this way, stand age and growth rates can be estimated. Such information is critical to understanding stand histories with respect to structural development and successional processes. This will be done before or at the time of the next round of monitoring.

vii). The area of all monitoring sites combined is 6.22 ac. Relative to the entire area of forest in CACO (roughly 26,000 ac), this is a very small percentage (~0.02%). As such, the plots will not capture many changes that occur within the forested area of the park. To detect these changes, analysis of aerial photography will be needed. At CACO, cover-type mapping has been conducted in 1990 and 2000 and will continue to be done on a decadal basis. This information will provide perspective on changes that are observed within plots and will also assist in the detection of changes that occur in remote areas outside the monitoring network. Other types of remote sensing, such as LIDAR, may also be very useful in analyzing broad changes in forest structure.

Environmental Variables

This version of the protocol does not include any direct sampling of environmental (abiotic) parameters. One reason for this is that several of the more-important factors influencing forest ecosystems can be very difficult to sample effectively. For example, soil moisture frequently exhibits a high level of spatial and temporal variability such that instantaneous measurements can be relatively meaningless. To adequately characterize the amount of moisture available to the entire mass of tree roots within a module, samples would have to be drawn from multiple depths at multiple locations several times between June and August. This represents a substantial investment of time and labor. Even then, the investigator would be left with trying to correlate various patterns of tree growth that have occurred over a ten-year period (the time between surveys) with hydrologic conditions characterized during a single growing season. Soil chemistry sampling and analyses face the same issues. However, precipitation amounts and quality, groundwater levels, land surface topography, and soil chemistry data are available and can be used to provide some perspective on hydrology, water quality, and substrate conditions across the site network. It is pertinent to note that Chokkalingam (1995) suggested that soil moisture and land-use history are important factors regulating species composition.

CACO does have access to a large quantity of air quality data from a site within the park that is part of the National Atmospheric Deposition Program (NADP) (ref). This information may be useful in analyzing long term changes in forest structure or composition.

Number and Location of Sampling Units

There are currently a total of 39 sites (15 of the original 21, and 24 new) representing eight primary community types delineated on the 1991 CACO vegetation map (beech, pitch pine, pitch pine-black and white oak, black and white oak, pitch pine-heathland, red maple, black locust, Atlantic white cedar) within CACO. The sites were randomly placed within the mapped polygons of each type. In total, they cover the entire geographic range of CACO and are easily

accessible from existing paved and dirt roads. Appendix B includes detailed maps and descriptions of each location.

Frequency and Timing of Sampling

Chokkalingam (1995) and Barron (2004) showed that significant changes in species composition were detectable over a 10- to 12-year period. Thus, we propose the frequency of sampling to be every 10 years, which is similar to the interval between surveys since 1981. All sampling is conducted during the summer months of June through August.

Detecting Trends

In 2001, data were collected within the modules and at the fire stakes. While the modules were a fair representation of forest habitat throughout the larger fire stake network, comparisons of these datasets reveal that tree DBH, densities, and basal areas are just too different for any rigorous analysis of temporal trends (Appendix A). Such differences, however, are not critical to the success of long-term monitoring. Although it is preferable to have the consistency of one method throughout the entire history of monitoring and/or a near perfect correspondence between variable-radius and fixed-area plot data, transitioning to a new protocol only partially limits analyses of temporal trends. In this regard, changes over the last 20 years have already been evaluated using the variable radius plots (Chokkalingam 1995, Barron 2004) while changes over the next 20 years (and beyond) can be assessed using data from the fixed-area plots. If it is ever considered necessary to make comparisons over a period of time that bridges the transition point (2001), this can be done by re-sampling the fire stakes by the variable-radius plot method (Figure 5). Doing this would also be useful for determining whether the module-based sampling is capturing the same kinds of changes as point sampling. To a certain degree, the limited spatial coverage that modules provide relative to the fire-stake networks is compensated for by the larger number of sites (see above under "Revisions to Spatial Scales and Frequency").
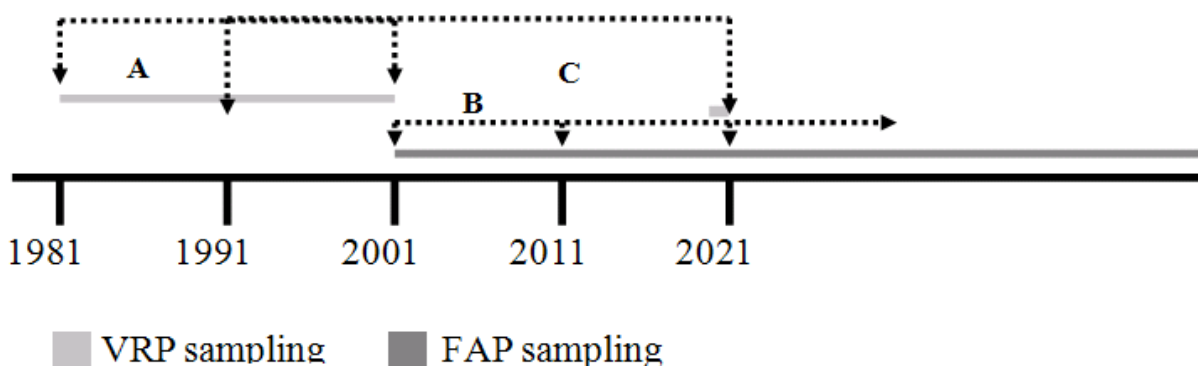
Figure 5. Diagram showing various timeline comparisons that are possible with both sampling methodologies. Analyses of change during 1981–2001 (A) using the variable-radius plots (VRP) are available in Chokkalingam (1995) and Barron (2004). Future trends (B) can be analyzed based on 2002–2003 module fixed-area plot (FAP) data as the starting point. Analysis of trends over the transition period (C) will require sampling by the original (variable-radius) method.

Power Analysis

As described above, data collected by the variable-radius (fire stakes) vs. fixed-area (modules) plots are not directly comparable by statistical analysis. Given the proposed transition to fixed-

area sampling, variable-radius plot data are not examined here. A summary of 2002/2003 fixed-area plot data is presented in Appendix C. Because a secondary survey is lacking for the modules (i.e., data for time 2), temporal changes in important variables were simulated by calculating 20% and 50% shifts in mean values (over a ten-year time period) calculated from the 2002–2003 dataset. These criteria are similar to those used in the Shenandoah NP Vegetation Inventory and Monitoring Program (Diefenbach and Mahan 2002). Although using simulated data is not the ideal way to assess power, it provides a useful preliminary assessment until more rigorous analysis can be done comparing two actual datasets.

Regression modeling served as a basis for deriving reasonable estimates of standard deviations for simulated means. Where means and their standard deviations were significantly correlated, the regression equations were used to estimate standard deviations for the simulated means. Where no correlations existed, the same standard deviations were used for actual and simulated means. This was also done in cases where standard deviations were negatively correlated with means (values decrease with increasing mean values) so that power would be conservatively estimated.

All data were log-transformed in order to meet the assumptions of normality and reduce heteroscedasticity. Simulated shifts in population means were then calculated as mean $\pm$ (20% or 50% of mean). Using the statistical analysis software DSTPLAN™, developed by Brown et al. (2002) and provided online by the University of California Los Angeles Department of Statistics, T-tests were run (α=0.05) to calculate power. Since we were interested in testing two directional hypotheses (i.e., H_0: $\mu_1 \leq \mu_2$; H_1: $\mu_1 \geq \mu_2$), one-tailed tests were used for each case of positive and negative change. Restricting the region of hypothesis rejection to one tail of the sampling distributions provides greater power with respect to the alternative hypothesis (H_1) in the direction of that tail (Edwards 1972). Although there are no universal standards for power, it has been widely accepted that power should be at least 0.80 - i.e., one should minimally have an 80% probability of detecting a departure from the null hypothesis of no change.

There are many permutations of power analysis that can be done within the framework of this monitoring design and not all are presented here. Only data and groupings of data considered most informative to scientists and managers were analyzed. In this regard, tree diameter at breast height (DBH) is an important variable since it directly describes tree girth and is closely related to tree height, canopy area, and basal area. Basal area (BA), which indicates the area of tree stem/trunk per m^2 of sampling area, integrates both DBH and tree densities and is another critical variable describing tree growth and population dynamics (Horn 1971). Calculations of power to detect changes in species composition is commonly done using methods that compare similarity or dissimilarity matrices of two datasets collected at different times (Philippi et al. 1998, Roman et al. 2001). With the absence of a secondary dataset, however, such tests are not possible. Moreover, hypothetical shifts in community composition cannot be realistically simulated, as there are innumerable ways in which the relative abundances of taxa can change; thus, for analysis of community-level changes, a univariate measure of species richness, the Shannon-Weiner diversity index, was calculated from tree data (both densities and basal area) and compared to hypothetical deviations in these values.

Power to Detect Changes in Total Tree DBH and BA Over Entire Site Network
Standard deviations and means for total tree DBH (all species pooled) were negatively correlated (R^2=0.32, p≤0.001). According to this relationship, estimated standard deviations for means representing a +20% change would theoretically be lower and, therefore, the power to detect this change higher (provided the number of replicates in the second data set does not decrease substantially). To be conservative in estimating power, however, we felt it prudent to use the higher (actual) standard deviations for the simulated means as well. When this was done, the power to detect changes in total tree DBH was still very high (≥95%) (Appendix D).

For BA, each site value represents the sum of all trees within that site, so there is no associated variance. Consequently, no relationship between site BA values and standard deviations could be determined. Analysis of individual modules (which provide replication within a site and, therefore, standard deviations) suggests that means and variance are, in general, positively correlated. The regression models, however, were highly variable with respect to slope and goodness of fit. Accordingly, standard deviations for simulated network-level means were calculated simply as percentages of means based on the relationship of these two values (i.e., standard deviation/mean) in the original data. For example, a mean BA value of 4 with a standard deviation of 2 translates to a conversion factor of 0.5 (i.e., standard deviation is 50% of mean). Thus, for a mean value of 4.8, which represents a +20% change, a standard deviation of 2.4 was used for the analysis. By this approach, the power to detect a +20% and -20% change in total tree BA over the entire site network was 56% and 71%, respectively. The power was much higher (100%) for a 50% change in either direction (Appendix D).

Total tree densities for each site are also single values that represent the sum of all trees within each site. Like BA, therefore, regression modeling of variance cannot be done for this particular data grouping and standard deviations were adjusted by their corresponding conversion factors. Power to detect a +20% and -20% change was 53% and 99%, respectively, and 100% for a 50% change in either direction (Appendix D).

Power to Detect Changes in Total Tree DBH and BA at Individual Sites
For an individual site viewed as an entire entity (i.e., as one 400m^2 module), there can only be one standard deviation value associated with mean DBH (all species) and relationships between mean DBH and variance cannot be modeled. However, mean DBH values that represent individual modules (n=4) within a site and their variances can be. When this was done, only negative or insignificant relationships emerged. As in previous analyses, values computed from the actual data were used for simulated populations.

Overall, the power to detect changes in tree DBH (all species pooled) at individual sites varied substantially. At a 20% level of change, 19 out of 39 sites had power values ≥80%. At a 50% level of change, however, detection power was ≥88% at all sites (Appendix D). Mean site BA values and their standard deviations were not correlated and the same values were used. The power to detect changes in total tree BA at individual sites was generally good with values ≥80% at 31 out of 42 sites for a 20% change, and at 35 out of 39 sites for a 50% change (Appendix D).

Power to Detect Changes in Individual Species DBH and BA Over Entire Site Network
For individual species, mean DBH values were either negatively or not significantly correlated with their standard deviations. Again, to err on the side of caution, the original standard

deviations (larger values) were used for the simulated means. The power to detect DBH changes of 20% in individual species was ≥80% in all taxa except *Amelanchier* spp. (shadbush), *Fagus grandifolia* (American beech), and *Nyssa sylvatica* (black gum) (Appendix D). Changes of 50% generated power values of ≥89% and above.

Based on analyses of data from individual modules (n=4 per site), standard deviations were typically positively correlated with mean BA values. Standard deviations for simulated network means were subsequently calculated from regression models for each species. Since site BA values are sum totals encompassing all DBH values, there exists only one value per site with no standard deviation. As such, power cannot be computed.

Power to Detect Changes in DBH and BA of Individual Species at Individual Sites
The power to detect changes in individual species was generally higher among sites designated as being of that particular species type. For example, the power to detect changes in pitch pine DBH was 100% within the subset of sites designated as pitch pine type (with the exception of CC02). In contrast, power values ranged between 7% and 100% for a 20% change in pitch-pine DBH within other forest types. By contrast, changes of 50% translated to power values ≥92% at all sites except one (CC24) (Appendix D). This pattern was similar among all species tested.

Mean BAs of individual modules (n=4) were determined and, from these values, site means with corresponding standard deviations calculated. The regression equations describing correlations between BA and standard deviations for each species (see above section) were used to generate standard deviations for simulated means at individual sites. As a whole, the ability to detect changes in mean BA (average of four replicate modules) of individual species at individual sites was very low (data not shown).

Power to Detect Changes in Tree Seedling Densities
There was little power to detect changes in population means of tree seedling densities either by site (all species pooled) or by species (all sites pooled) - a result similar to that found for monitoring data from Shenandoah National Park (Diefenbach and Mahan 2002) (data not shown).

Power to Detect Changes in Overstory Species Composition Over Entire Site Network
Analysis of data grouped by individual modules suggested that no relationship existed between means and standard deviations for Shannon-Weiner diversity. Accordingly, the same standard deviations were used for comparisons. For diversity indices calculated from BA data, the power to detect a 20% change was low (32%), whereas the power to detect a 50% change was high (90%). For indices calculated from tree densities, the two values were respectively higher (42% and 93%) (Appendix D).

Power to Detect Changes in Understory Species Composition Over Entire Site Network
Shannon-Weiner diversity indices were calculated from log-transformed mid-point values of percent cover classes and compared to hypothetical deviations from these values in the same manner as was done for tree-related variables. The results showed that community-level shifts of 20% and above could be detected with a very high level of confidence (≥99%) (Appendix D).

Power Analysis – Conclusions
Overall, the ability to distinguish between actual vs. hypothetical population means was variable. The sampling program appears adequate for detecting changes in total tree and species-specific DBH at both the site and network levels. Large changes in total tree BA throughout the site network and at individual sites could also be detected with a high degree of certainty, but not for individual species. The power to detect shifts in species diversity indices was limited to large changes in overstory, but sensitive to smaller changes in the understory.

Despite the inability to statistically parse the actual and simulated means of certain variables, the results are encouraging, given that the analyses used very conservative (i.e., large) estimates of variance for simulated means. The negative relationship between DBH values and their standard deviations is somewhat puzzling, but suggests, perhaps, that as the forest matures and becomes dominated by large trees, there is a corresponding decrease in very small individuals that would otherwise contribute to variability. Notwithstanding, it should be noted that significantly more power to detect change in certain variables could be gained by omitting understory trees (i.e., trees with DBH <10 cm) from the analyses or by stratifying data in other ways. In fact, grouping data by DBH class is a logical and commonly practiced technique for analyzing specific segments of tree populations, and one that greatly shrinks variability that diminishes power. As a striking example, the power to detect a 20% change in DBH for the entire *Pinus rigida* population at site CC15 was 33%. When the analysis is limited to individuals with DBHs ≥10 cm, however, the power increases to 100%. This is an important consideration in evaluating the protocol at this stage of its development. Given the enormous effect that data stratification has on detection power, we feel it is too soon to recommend adding sites to the monitoring network solely for the purpose of increasing power. Another important consideration in evaluating these analyses is that power has already been gained (although the magnitude cannot yet be determined) by virtue of the fact that each tree has been tagged with a unique number. As such, the growth of the same individuals can be monitored through time, which allows for testing by paired, rather than independent, observations or by repeated measures ANOVA.

Counts of tree seedling densities will have to be rigorously evaluated as to its value to the monitoring protocol, but not until after a second dataset has been collected. Although changes in seedling numbers may not be detectable at a statistically acceptable level, this is not the main objective for monitoring this parameter. Rather, we are interested in how many seedlings/saplings from the understory population grow into the overstory layer and whether overstory species abundance is a function of the number of potential recruits - a dynamic that cannot be analyzed at this time. In fact, all the analyses discussed above are somewhat premature, considering that another actual dataset is not yet available for comparison. Moreover, it is changes in community composition that is perhaps the most important trend that this monitoring protocol attempts to capture. Unfortunately, for the purpose of power analysis it is impossible to simulate how communities will deviate from their current constituency. Regardless, a fixed-area sampling design in which individual trees can be followed through time virtually guarantees that changes within that area, should they occur, will be documented.

Field Methods

The following sections provide an overview of field operations. These procedures are described in more detail in the SOP section of this document.

Field Season Preparations and Equipment Setup

Prior to the field season, it is important that the lead biotech set aside some time to become intimately familiar with the vegetation he/she is likely to encounter and the process of identifying unknown specimens. Field guides (see SOP#2) and electronic documents summarizing key morphological attributes for identifying species are available in CACO's North Atlantic Coastal Laboratory (NACL) library and on the NACL server.

The entire crew, including the project manager, also must make sure that all equipment is available (see Equipment list in SOP#1) and in working order before use. Before conducting the actual sampling, vegetation data from the last (most recent) survey should be extracted from the database so that it can be used as a reference, if needed. Finally, both members of the field crew should review the entire protocol and make sure that they understand all the components of sampling, quality assurance, and data management.

Sampling Procedures

A detailed "cookbook" outline of the sampling procedure can be found in SOP#5. After successfully navigating to a site, the field crew will establish the boundaries of each modular plot using rope strung from marker to marker. The crew will then determine the arrangement of the modules (i.e., which modules are 1, 2, 3, and 4) and begin collecting data. The order in which data is collected is not critical.

For overstory vegetation (i.e., trees >2 m), individual trees are assessed for DBH and health condition. Tree densities do not have to be determined in the field, as they can be calculated by summing the number of DBH observations for each plot. However, the height of the tallest tree in each module is estimated. Tree seedlings/saplings <2 m are also counted by module. Visual estimates of near-ground (shrub) and ground (herbaceous, sub-shrub) cover by species are done within the smaller, nested plots. Estimates of canopy cover are obtained by acquiring hemispherical digital images at specific photo points and analyzing them with imaging software.

End-of-day Procedures

Upon returning from the field, any voucher specimens collected as unknown specimens should be identified (see SOP#5). Field notes/datasheets should immediately be checked for completeness and accuracy and then photocopied. The backup copies should be stored in a separate folder, preferably in a separate location. If there is time, it is advisable to enter data the same day that it is collected. Alternatively, one day a week can be set aside for this purpose. As a general rule, the time between data collection and entry should be minimized to the greatest extent possible and in no case should be longer than one week.

Throughout the day, and especially at the end of the day, each crew member should check themselves and each other for attached ticks. If any are discovered, they should be carefully removed in a manner prescribed in the "tick safety" presentation – a Powerpoint file located on

the NACL server. The victim must then fill out a safety documentation form and submit it to the project manager, who will then forward all information to the Chief Safety Officer.

End-of-season Procedures
At the completion of the field season, the lead biotech is responsible for writing an end-of-season report. The report should outline the activities undertaken, summarize key findings, and discuss any problems or issues that arose and suggestions for revisions/improvements. The crew must thoroughly inspect all the equipment to ensure that each item is in working order and a list of items that need replacing or repair is compiled. The vehicle assigned to the forest monitoring crew for the season should be thoroughly cleaned.

All field workbooks, datasheets, and notes should be organized and given to the project manager for safe keeping. It is imperative that the all the data be entered into the electronic database before the field crew leaves at the end of the season.

Data Handling, Analysis, and Reporting

Overview of Data Procedures

SOP#7 provides a thorough overview of data management, including metadata, database design, data handling (entry, verification, reporting, extraction, and editing), and data archiving. A data dictionary is also included in this section. SOP#6 provides procedures and standards for reporting results.

In terms of quality assurance/quality control (QA/QC), this protocol incorporates a number of different procedural elements designed to maintain a high level of integrity. For example, the collection of field data involves thorough training of personnel and the implementation of standardized field procedures. Hardcopy documentation of all data is maintained in field notebooks and duplicate copies stored separately. Data entry is completed at the end of each day or, when this is not possible, within a week of when the fieldwork was conducted. Data entry is done with two people to assure accuracy and improve probabilities that errors will be detected.

A number of built-in controls, such as range limits and look-up tables, have been incorporated into the database as a means to assure data quality (see previous section). Once the data has been entered, each entry is double-checked or "proofed" for verification of accuracy. As an additional QA/QC check, the project manager should examine at least 10% of the data to look for illogical or obviously mistaken values (e.g., outside possible range limits), spelling errors, inconsistencies in naming conventions, duplicate records, etc. Any changes to records will be duly noted on the original field forms (Appendix E) so that the electronic and hardcopy data forms match. Once the project manager has gone through this process of validation, the data will be saved to the NACL server (Y drive).

Recommendations for Routine Data Summaries and Statistical Analyses

There are many different ways in which to analyze the data. Kent and Coker (1996) can be consulted for a comprehensive view of vegetation description and analysis. In general, analyses should be based upon the kinds of research or management questions driving the monitoring. Changes in the floristic composition of understory and, particularly, overstory strata will almost always be an important issue. For cover class data, ordination techniques are an excellent way to describe spatial and temporal variability. Cover class values are replaced by the mid-point percentages of their representative ranges and will likely require transformation of some kind (e.g, square root, logarithmic) in order to meet with assumptions of normality. Changes in species composition over time and space can be illustrated using Principle Components Analysis, Multidimensional Scaling, Clustering, and Analysis of Similarity.

For univariate data, the means and standard errors of the mean (standard deviation divided by the square root of the number of samples) should be calculated and plotted as histograms. To examine temporal shifts, mean values calculated from different surveys (e.g, 2002 vs. 2012) can be compared. For example, it would be informative to show how overall tree growth (i.e., all species pooled) or the growth of particular species has proceeded over time as indicated by DBH or BA data. Statistical validation of such changes can be conducted using paired or independent T-tests or repeated measures ANOVA. Regression analysis can also be used to assess longer temporal trends – for example, the rate of growth of *Q. alba* over the last three sampling periods (note: regressions should be based on at least three datasets, since a line cannot be defined by

only two points. Parametric data (e.g., Basal area) from all four modules at each site can be combined to obtain sums for the entire 400 m^2 area. Subsequently, among-site comparisons can be conducted. Individual modules can serve as replicate samples if there is a desire or need to assess within-site variability. Non-parametric data, such as cover, can be transformed to the mid-point percentages for each class (e.g., 26–50% class = 37.5%) so that a mean percent cover value can be obtained for the site as a whole (derived from the four modules).

Recommended Reporting Schedule
Because the interval between sampling events will be in the range of ~10 years, reporting should be done after every season of fieldwork to assess decadal trends. The report should include background information about the project, a summary of what was accomplished during the season, and some basic analyses of the data (see previous section).

Personnel Requirements and Training

Roles and Responsibilities
General oversight and implementation of the protocol is provided by the Project Manager, which, ideally, will be a Plant Ecologist or Botanist. The project manager's specific duties include: staff selection, training, and supervision, data analysis, reporting and interpreting results, and protocol evaluation. The protocol can be carried out with two seasonal biological field technicians (biotechs) or a biotech accompanied by a student intern/volunteer. In the case of the former, each biotech can take turns doing the sampling while the other records the data. In the latter situation, the biotech should be responsible for acquiring the data (i.e., actually doing the measurements, counts) while the assistant fills out the field datasheet. The lead biotech will also supervise all aspects of data processing, including several aspects of QA/QC, such as data entry and proofing. The Project Manager is responsible for coordination with the Data Manager to ensure that information is collected in a way that will be compatible with the existing database structure. The Inventory and Monitoring (I&M) Coordinator provides supervision and oversight of CACO's Prototype Monitoring Program and is responsible for ensuring that all project, Program, NPS, and scientific standards are met.

Qualifications and Training
The ability to make rapid, accurate IDs in the field is critical to completing fieldwork in a timely manner. Minimally, the lead biotech should be very familiar with the majority of plant taxa likely to be encountered. Where deficiencies occur, the project manager should assist the technician in developing the knowledge and skills required for identification (including the use of field guides, etc.). For unknown species that cannot be identified in the field, the crew must be able to use taxonomic keys and other relevant materials for confirmation back at the office or laboratory. It is extremely helpful to allot some time prior to sampling to become familiar with the plant communities of the monitoring network and to develop skills in estimating percent cover (see SOP#5).

Ideally, both members of the field crew will have a good working knowledge of forest mensuration techniques and plant community ecology. Additionally, both members of the field crew will be trained in the following areas:

- Implementation of the specific field procedures and methods in this protocol
- GPS navigation and compass use
- Tick bite prevention and treatment
- General field safety (e.g., prevention of poison ivy, heat exhaustion, etc.)
- Vehicle safety and driving etiquette
- Equipment maintenance and storage
- Use of two-way radios
- Computer use guidelines
- Data entry and basic principles of data QA/QC, database functionality
- Data storage guidelines

Operational Requirements

Annual Workload and Field Schedule

To complete data collection in a timely manner for all 39 sites, the field crew should plan to visit two (2) sites per day. This totals roughly 20 days or the equivalent of four (4) weeks of field work and provides an adequate buffer for cancellations due to inclement weather. It also ensures enough time for establishing decomposition dowels, identifying unknown specimens, data entry, and writing an end-of-season report.

If possible, it is advantageous to acquire tree-related data in the winter-spring period when plot markers and tree tags are highly visible due to the absence of understory foliage. Also, it is much easier to maneuver around at this time, especially when the water is frozen in the forested wetlands (red maple, Atlantic white cedar). *Note: an ice thickness of at least 4 inches is necessary to safely support the weight of an adult.* Unfortunately, the availability of field technicians is often limited to summer months; in which case, fieldwork should begin no later than ~June 20. Understory and canopy cover data should only be collected when all species have leaves (ca. June through September). This period may vary somewhat among different years due to climatic variability.

Facility and Equipment Needs

The field crew will require use of normal office space and a computer linked to the local NACL server. Internet connectivity is also desirable as plant identification and general research can be aided by referencing various websites, such as the U.S. Department of Agriculture PLANTS and other databases (see SOP#2). A small amount of additional space will be necessary for storage of unidentified plant specimens. The crew will also require a vehicle (preferably a pick-up truck) with four-wheel drive capability. All other equipment needs are listed in SOP#1.

Startup Costs and Budget Considerations

Project-specific costs are primarily limited to personnel, which includes a plant ecologist/botanist and either two biological technicians or a biological technician and a student intern/volunteer. The I&M Coordinator and Data Manager will also contribute to overall staffing costs for the project. Other costs will generally be related to equipment repair and replacement, vehicle maintenance, etc.

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Standard Operating Procedure (SOP) #1. Preparations and equipment setup prior to field season.

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #1
Preparations and Equipment Setup Prior to Field Season

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

1.1 Preparation
To prepare for the field season, the field crew is advised to complete the following activities:

1. Review the entire protocol
2. Review species lists and characteristics for identification
3. Retrieve and review prior data for reference
4. Visit actual sites or similar habitats to become familiar with vegetation, practice identification skills, and rehearse setting up plots
5. Consult maps of sites and module locations
6. Inspect equipment and compile the items listed below

1.2 Equipment List
- DBH measuring tape
- Compass
- Datasheets/field notebooks
- Hammer, rubber mallet
- Tree tags with unique ID numbers
- Aluminum wire
- Flagging tape
- GPS unit with site coordinates
- Hardcopy map of site locations with plot layout diagrams
- List of species previously found in plots
- Plant identification materials (field guides, digital images, etc.)
- Waders (for wetland sites only)
- Rope on a spool to delineate plot boundaries
- Insect repellent
- Pre-contact solution for prevention of poison ivy and poison sumac

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #2
Training Observers

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

2.1 Identification of Plant Taxa

At the beginning of the season, the project manager (botanist, plant ecologist) should take the field crew out to actual sites or similar habitats and review as many different taxa as possible. It is also advisable for the field crews to sit down with a list of species they are likely to encounter and study characteristics, images, or actual samples from the NACL or Salt Pond Visitor Center herbaria.

In addition, the following guidebooks are recommended for plant identification:

- Dwelley, M. J. 2000. Trees and shrubs of New England. Down East Books: Camden, ME.
- Gleason, H. A., and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. New York Botanical Garden: Bronx, NY.
- Holmgren, N. H. 1998. Illustrated Companion to Gleason and Cronquist's Manual: Illustrations of the Vascular Plants of Northeastern United States and Adjacent Canada. The New York Botanical Garden: Bronx, NY.
- Magee, D. W., and H. E. Ahles. 1999. Flora of the Northeast: A manual of the vascular flora of New England and adjacent New York. University of Massachusetts Press: Amherst, MA.
- Newcomb, L. 1977. Newcomb's wildflower guide. Little, Brown and Company: Boston, MA.
- Stuckey, I. H., and L. L. Gould. 2000. Coastal Plants from Cape Cod to Cape Canaveral. University of North Carolina Press: Chapel Hill, NC.
- Svenson, H. K., and R. W. Pyle. 1979. The Flora of Cape Cod. Cape Cod Museum of Natural History: Brewster, MA.

The following web sites are also recommended:

- http://plants.usda.gov/
- http://www.ct-botanical-society.org/docs/fernchart.html
- http://www.ct-botanical-society.org/
- http://hua.huh.harvard.edu/FNA/

2.2 Establishing Plots and Collecting Data

The project manager will rehearse the procedure of setting up a plot and going through the data collection procedure. Ideally, this practice session would be conducted at an actual site so that useable data can be collected. During this training period, the crew will receive instruction on how to properly fasten tree tags, ocularly estimate percent cover and maximum tree height, and measure tree girth using a DBH tape (see SOP#4).

Standard Operating Procedure (SOP) #3. Using the global positioning system.

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #3
Using the Global Positioning System

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

3.1 General Use

Keep the GPS unit dry at all times. In wet conditions the unit should be placed inside a clear plastic bag. This will not interfere with its ability to function properly. Do not leave the unit on for long periods of time between use, as the batteries will drain quickly. When crossing waterbodies (tidal creeks, ponds, streams, etc.) the unit should be kept in a waterproof container or pouch. If the unit is accidentally dropped into water, do not attempt to turn it on. Return to the office and consult with the GIS Specialist for the proper course of action.

Satellite reception may vary substantially depending upon interference from trees, topography, structures, weather, and satellite configurations. The unit should be held face up (i.e., the display screen facing upward). Also make sure that the antenna is pointing skyward.

3.2 Recording Points

GPS coordinates for module (center points) and fire stake locations were collected with a Garmin (GPSIII Plus) using the point averaging function. The data points were saved in the unit, uploaded onto a PC, and saved as an excel file named "coastal_forest_site_locations" on the NACL server (Y drive). The datum for all coordinate values is NAD-83 and the coordinate system is Universal Transverse Mercator (UTM) (Zone 19T).

To record new points on Garmin GPSIII Plus units, follow this procedure:

- Press the "menu" button (starting from any screen) twice.
- Highlight the "Waypoints" option and hit "Enter".
- Press "menu" again and select "New Waypoint".
- Hit the "menu" button one more time, select "Average position" and press "Enter".
- Wait until a satisfactory accuracy level (shown onscreen under "estimated accuracy") is obtained (usually requires measurement counts of >100)

3.3 Navigating

Thick canopy cover presents a problem in navigating with GPS units in that satellite reception is significantly hindered. In such cases, it is advisable to move into any open areas in the nearby vicinity. If satellite reception is still poor, it will be necessary to use hardcopy maps of the sites. For more information on the use of GPS technology, refer to the technical manuals located in the office o the GIS Specialist.

A programmatic SOP for use of GPS for all CACO monitoring projects is in development. In the future, this SOP will be incorporated by reference and adapted, as necessary, for this protocol when it is completed.

In the meantime, standards will be established and training provided in collaboration with the GIS Specialist.

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #4
Establishing and Marking Plots

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

4.1 Site and Plot Information

UTM coordinates, maps, and descriptions of how to access each site can be found in Appendix B and as electronic files on the NACL server. Between 10 and 40 rebar stakes mark the original Patterson variable-radius plot locations. The modular plots are oriented around one (1) to several of these stakes, depending on the site. The corners of each modular plot are marked with ¾" PVC stakes and trees within the plot are tagged.

4.2 Establishing the Plots

Find the rebar stake around which the module or cluster of modules is oriented. Then use field tapes (50–100 m) to delineate the boundaries of each plot by walking the tape between PVC markers (the specific layouts of the modules can be found in Appendix B). Additional field tapes are used to establish the 10-m^2 nested plots, while a PVC frame is used for the 1-m^2 plots. As a rule, the nested plots are always placed in the corners of each module.
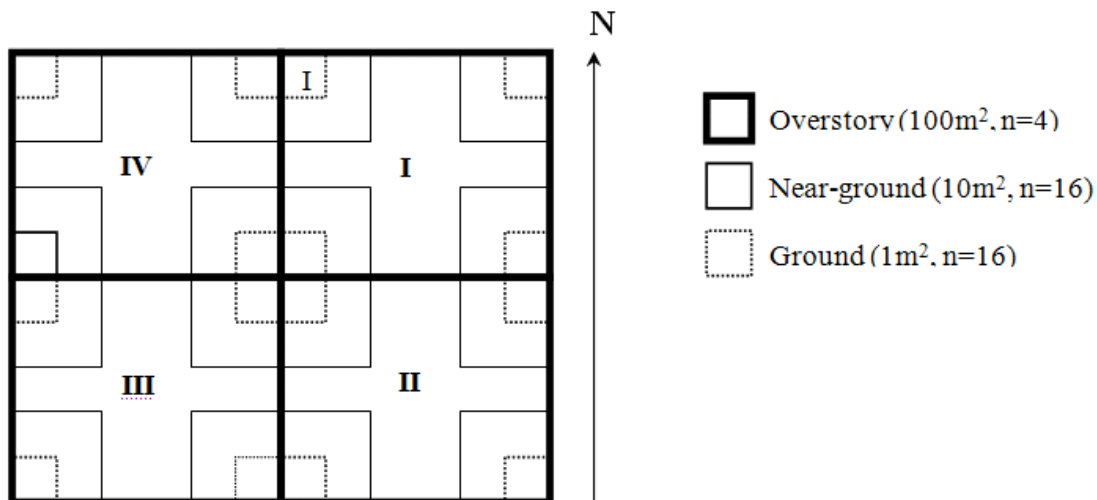
4.3 Schematic of Module Plot Setup

If one or more PVC corner markers cannot be found for some reason, the plot can still be set up using compass bearings. In addition, the tree tags will be helpful in delineating the sampling areas, since the crew will know which trees are in or out of specific plots.

4.4 Tagging Trees

Tree tags should be nailed (using at least 4 in. galvanized nails) or tied (using aluminum wire) to all overstory trees present within the modules. When new tags are needed, tags are placed 20 cm above the point at which DBH should be measured, which is 1.37m (4.5 ft.) above the base of the tree. When this is not possible (such as when trees have a contorted stem) the tag is attached to a point nearest the DBH point where it fits best (and the distance noted). For small trees with stems that are not wide enough to support a nailed tree tag, the tag should be fastened loosely (to allow room for growth) with aluminum wire.

Undoubtedly, many tree tags will need to be replaced at the time of the next survey to allow for further growth of the trees. Furthermore, it is quite possible that a substantial number of tags may be lost somehow during the time between surveys. It may be necessary to check on the state of the tags (as well as plot markers) every three (3) years, or so, and replace them as necessary. If this is not feasible, the entire tagging effort will have to be re-evaluated.

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #5
Conducting the Plot Survey

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

5.1 Overstory

Record the tag number, species, DBH, and health condition of every tree >2 m in height within each of the four 10×10-m modules. DBH is measured with a DBH tape - generally 20 cm below the nail that fastens the tags to the trees. In some cases, where the tags were fastened by wired or where the tree trunk was deformed or split, DBH is recorded at a different distance relative to the tag. All information pertaining to these specific points of measurements are noted in the forest database and in the plot profiles. In each module, also estimate the height of the tallest tree using the 2-m reference pole placed at the base of the tree, noting the species and tag number.

Count all tree species (i.e., any species that has the potential to become an overstory member) present as seedlings or saplings below 2 m in height. It is easier to do these counts if each module has been sectioned into three parts. To do this, simply lay two field tapes across the module (parallel to each other) to divide the area into three "lanes," and then tally by lane. For some trees, such as bear and black oak, multiple stems may protrude from the ground that are all part of the same individual plant. Count every stem as though it were a separate individual, since each has the potential to grow into the overstory and function more or less as an individual tree

In noting tree health, assign a number to each tree according to the index below:
1=broken bole; 2=canker; 3=gall tumor; 4=conk; 5=resinosis; 6=damaged (other types of breakage); 7=dead; 8=discolored; 9=other (describe).

5.2 Near-ground Layer
Within the 10-m^2 nested plots (n=16), total cover and cover of all shrub species ≥0.5 in. in height (except where noted for red maple, Atlantic white cedar, and black locust understory; see Narrative) is estimated visually and recorded as a numerical value ranging from 1 to 9 according to the following scale: Trace=1; 0–1%=2; 1–2%=3; 2–5%=4; 5–10%=5; 10–25%=6; 25–50%=7; 50–75%=8; >75%=9. All species not recorded within the nested plots but present within the 100-m^2 module boundaries are recorded as "present." For a review of techniques for estimating percent cover of vegetation, refer to the following document:

> *British Columbia Ministry of Environment, Lands and Parks and Ministry of Forests.*
> *1998. Field Manual for Describing Terrestrial Ecosystems. BC Ministry of Environment,*
> *Lands & Parks and Ministry of Forests, Victoria, BC*

5.3 Ground (Herbaceous and Sub-shrubs) Layer
Within the 1-m^2 nested plots (n=16), ground cover by species ≤0.5 m in height is estimated by eye and recorded as a numerical value ranging from 1 to 9 according to the following scale: Trace=1; 0–1%=2; 1–2%=3; 2–5%=4; 5–10%=5; 10–25%=6; 25–50%=7; 50–75%=8; >75%=9. All species not recorded within the nested plots but present within the module boundaries should simply be recorded as present (no cover class value assigned).

5.4 Canopy Cover (Still Under Evaluation)
Canopy cover, or canopy photos, use the Nikon 995 Coolpix digital camera (or functional equivalent) fitted with a Nikon FC-E8 fisheye converter. Proceed to the photopoint location (provided in Appendix C), aim camera toward the sky in a vertical plane at a level of 2 m, and take photo. Note: photos should be taken around mid-day on a day with heavy, homogeneous cloud cover, as bright sunlight will adversely affect picture quality and cause difficulty in processing.
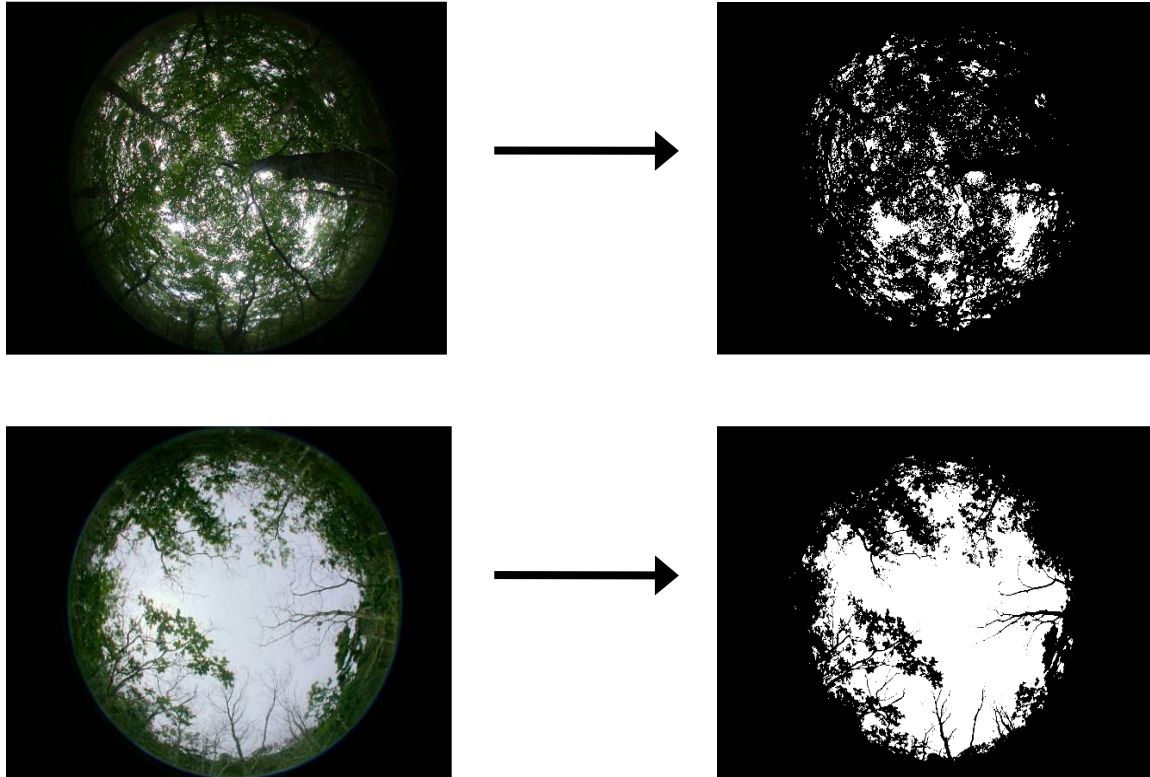
Unprocessed (left) digital photographs and their translation to two-color (black and white) images (right) for pixel counting.

Follow the steps below for image processing and analysis using LViewPro™ software (note: this can be done using other kinds of image analysis software):

- Download images from the digital camera using the card reader.
- Open selected image in LViewPro™ software
- Resize the image to 25% of the default setting by going to IMAGE > RESIZE.
- Next, go to COLOR > ADJUSTMENTS menu.
- Select the contrast function and set it to "10"
- Click on "Apply" as many times as it takes to convert the image to virtually all black and white pixels.
- The Logarithmic brightness function (set to a value of 10) can be used to lighten the sky before doing the previous step if some of the sky is being converted to black. Use the contrast and logarithmic brightness controls in different combinations to achieve optimal translation.
- Then close out of this window and go to COLOR > COLOR DEPTH.
- Enter "2" in the box next to the text that says "create a palette with exactly …"
- Click off the box below this line that says "include the default Window's colors…"
- Click "OK"
- Go to COLOR > COUNT COLORS
- The first number in the results box is the count of black pixels (R,G,B = 0,0,0). The next number is the count of all white pixels (R,G,B = 255,255,255). Record these numbers.

- Calculate percent cover by # black pixels (corrected)/total number of pixels (i.e., black + white)
- Repeat for each image.

5.5 Identifying Unknown Species

In the event that a species cannot be identified in the field, a voucher sample should be collected. Specimens should be taken outside the plot area. Flowers or fruit, even if they are last year's growth, are very helpful in identification. In general, the specimens should appear "typical" and healthy, based on leaf shape, color, etc. In the case of small plants, roots or underground stems are also used in identifying specimens. Samples can be stored in a refrigerator on a short-term basis (i.e. ~1 week) or air-dried and pressed flat between 2 pieces of cardboard for long-term storage.

If no specimens can be found outside the plots, a small amount of material (i.e., a branch, or portion of the stem with a few leaves) should be harvested in a way that will not compromise the survival of the plant. If this is not possible or there is reason to suspect that the species may be rare with State or Federal status, a digital photograph can be taken instead.

There are several different tools available for identification. The simplest way is to tap into the expertise of the resident plant ecologist/botanist. Color photography, identification guides, taxonomic keys, and the NACL and Salt Pond Visitor's Center herbaria are other sources of information. As a last resort, if the specimen still cannot be identified, the plant should be listed as "unidentified <growthform>" in the database (e.g., unidentified tree/shrub/graminoid/fern etc.).

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #6
Reporting

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

6.1 Reporting

Three types of reports will be generated:

- Monitoring reports - regular and timely reports of results and documentation of work accomplished;
- Analytical reports - in-depth and integrative analyses of trends, identification of causal factors, and comprehensive assessments of resource condition and ecosystem integrity; and
- Protocol review reports - in-depth assessments of the efficacy of monitoring methods, the validity of design assumptions, and the overall utility of the protocol for answering the monitoring questions.

For most protocols, the frequency with which each type of report will be produced will vary according to the frequency of data collection and the objectives of each type of report. Coastal forest monitoring is unique among CACO's monitoring projects in that data collection will only occur every ten years. This frequency is appropriate for detecting the types and scale of ecosystem changes of interest. However, decadal monitoring could be considered rare compared to other projects and in the context of programmatic evolution, staff dynamics, and other organizational concerns. To facilitate continuity over the relatively long interval between rounds of data collection, it will be important to meet the documentation and analytical objectives of these three types of reports each time coastal forest vegetation monitoring occurs. This could be accomplished by producing three individual reports as called for in the programmatic SOP, or it could likely be accomplished in a more efficient manner by combining reporting objectives into one or two documents. Decisions regarding how to best meet these objectives are best left to the project manager and I&M Coordinator involved at the time each round of data collection occurs. As a result, reporting procedures will follow these guidelines:

- The documentation and analytical objectives of each type of required report will be met through production of one or more documents following each round of data collection;
- The manner in which the reporting objectives are met (e.g. one comprehensive report, a monitoring report and a combined analytical and protocol assessment report, etc) will be determined by the project manager and the I&M Coordinator; and

- The project manager and I&M Coordinator will make this determination and establish corresponding due dates for drafts within two months of completing each round of data collection.

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #7
Data Management

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change
1.0	June 2004	V. Decker	Original Draft	

7.1 Document Description

This procedure provides instructions and guidelines for the development, maintenance, and distribution of monitoring data and reports associated with the Coastal Forest Monitoring Protocol for Cape Cod National Seashore. This document describes the overall file management system, as well as the details of the monitoring data validation and storage in an Access database. It also contains information on how to obtain copies of the dataset.

7.2 Reference Documents

There are several supporting documents that are more useful as working documents that can be modified independently of this Standard Operating Procedure. They contain the detailed descriptions of the data structures and database application that stores the Coastal Forest data. The data management plan and the procedures referenced by the plan provide general information on the procedures used to manage all electronic data at Cape Cod. These documents are the:

- Cape Cod National Seashore Coastal Forest Monitoring Database Guide
- Cape Cod National Seashore Coastal Forest Monitoring Data Dictionary
- Cape Cod National Seashore Data Management Plan

The data dictionary and the database guide should be consulted before using or changing the monitoring database.

7.3 Definition of the Coastal Forest Data Set

The Coastal Forest Monitoring Program will produce a large number of electronic files that include formal written reports, geographic information system files, Microsoft Access databases, spreadsheets, and statistical analysis files, image files, chemical analysis, and paper datasheets. There is a collection of spreadsheets containing data collected in prior years using a different method than the long-term monitoring protocol described in this document. This data has value and will be considered part of the original Coastal Forest Data Set. There will also be ancillary information that may consist of scientific peer reviews, related studies by cooperators or other

agencies, various programmatic correspondence and history files, etc. The large number of files and the frequent revision of these files will require conscientious and formal attention to the management of the files that constitute the data set.

7.4 File Management

Current Files

The large number of databases, reports, GIS coverages, and images being assembled for the I&M program required the establishment of some Program rules for storing electronic assets. Figure 7.1 shows the top level file structure for the current files for the Coastal Forest monitoring project. Image files for the current season will be stored in a separate images folder to facilitate cataloguing of all image files at the Park with separate image management software. The I&M Project directory is intended to hold all current and frequently accessed files. An archive directory was established to house information for each monitoring program more permanently at the end of each year.
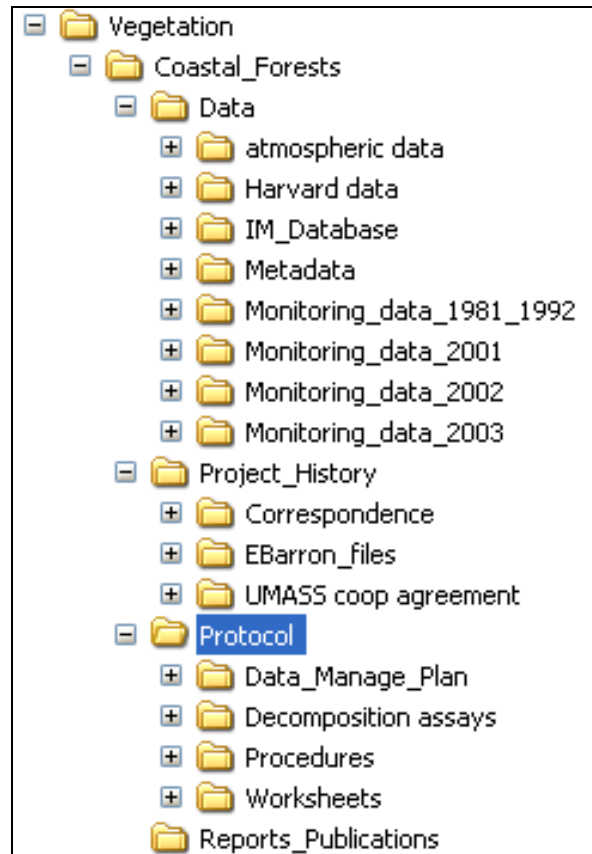

Figure 7.1. Top level coastal forest monitoring file structure.

Local Archiving of Files

This monitoring program is very long term. Information may only be updated every ten years, so permanent and well-documented archiving of the data is particularly important. At the

conclusion of each field and reporting season, all of the important electronic files will be organized, reviewed for accuracy, and catalogued. The data set will be stored in at least two local locations. The first storage location will be in the designated project archive on the local server. Files in the archive will be stored in read only format. The second location will be on a DVD that will be stored in another physical location. Paper worksheets and notes will be filed and stored.

Database files that are moved to an archive folder are considered permanent. Changes should not be made to these databases once archived. Copies of database files that are modified after archiving must include detailed revision notes stored in its internal database revision history table for reference. Any changes to data stored in an archived file must also be documented in a Word or text document stored in the same folder as the database. Whenever practical, data should not be changed via direct entry in a table. Queries should be developed to modify the data and stored in the database so that the changes can be tracked. Tables may be added to store old information.

The very long time horizon of this dataset and the infrequent use of the data call for some additional caution in storing the data. There is a possibility that the Access data file will not be accessible due to software obsolescence. Although the CACO Data Management Plan addresses this possibility, the most prudent path is to export all of the raw data in the database to a platform independent format. All table schema and data will be stored in XML format after final review of the protocol and the data.

Daily Server Backup Procedures

Tape backups of the archive directory and project directories will be made daily. Tapes are retained for at least two weeks before being overwritten. Tapes are held in a fireproof chest in the server room. Backup tapes will be taken off site at intervals not to exceed two weeks. Monthly tape backups are also made and held off-site.

2.5 Coastal Forest Monitoring Database Model

The coastal forest database table structure closely follows the NRDT January 2004 template core table structure with a few minor exceptions. The entity relationship diagram for the primary tables of the coastal forest database is shown in Figure 7.2.

There are three tables that hold monitoring information on coastal forest species diversity and condition. The first table, tbl_VUP_Tree_Condition, contains a listing of tagged trees, their diameter (DBH), maximum tree height in the module, and general condition on a given observation date. Table tbl_VUP_TreeSeedlingCounts contains counts of seedlings found on fixed plots (modules) at different points in time. The tbl_VUP_Taxa_Cover contains listings of the ground cover species and their abundance (Cover Class) in fixed plots on a given date. The primary key for all of these tables include an EventID.

Each visit to a forest or a plot is considered an event. Each event is defined by a location identified by a set of GPS readings, the date, and the protocol document in place at the time of the observations. The tbl_Events is the table that links information on location and time with monitoring measurements and observations. The primary key for this table is the EventID. This field is invisible on the data entry screen and in most output queries. However, the EventID links
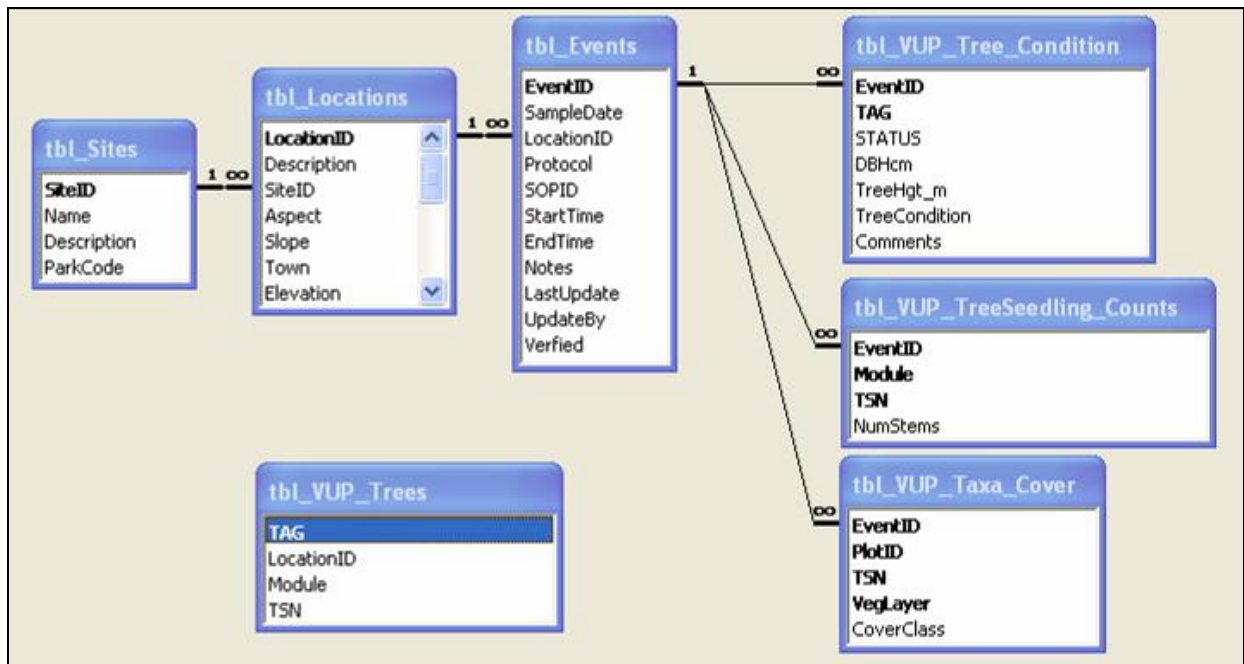
Figure 7.2. Coastal Forest Database Core Tables

information on the location, observation date, protocol, and operating procedure which can be used to link information in the database with the procedural documents in place at the time the observations were made. The only departures from the January 2004 NRDT template table structure were in the Event table. The location field was moved from the data fields to the event table so that there is a one-to-many relationship of the locations to events. An SOPID field was added to the events table to better track and isolate events associated with distinct monitoring procedures.

The tables tbl_Locations and tbl_Sites provide detailed geographic information associated with each sampling point. There are a number of supporting tables and look-up tables that are used to provide lists used to facilitate data entry. A list management screen is used to link species and observers with protocols and to restrict data sources on the many selection controls on the forms. A more complete entity relationship diagram is shown in Figure 7.3. These tables are described in detail the Coastal Forest Database Dictionary.

Plot images and canopy images are linked to the database and can be viewed in the database. Links to the image files are maintained with a separate form to allow image files to be moved and transferred with the database. Descriptive image file and folder names are used to ensure that image files are not disconnected from the database. Descriptive metadata for the images will also be stored separately from the monitoring database as an added file management aid.

Species are identified in the database by TSN numbers. Common and Latin names of the species should correspond with names accepted by CACO staff and NPSpecies. The species list should be verified at the start of each monitoring period so that the local species names will remain in synchronization with those adopted as the preferred TSN for the species by the park.

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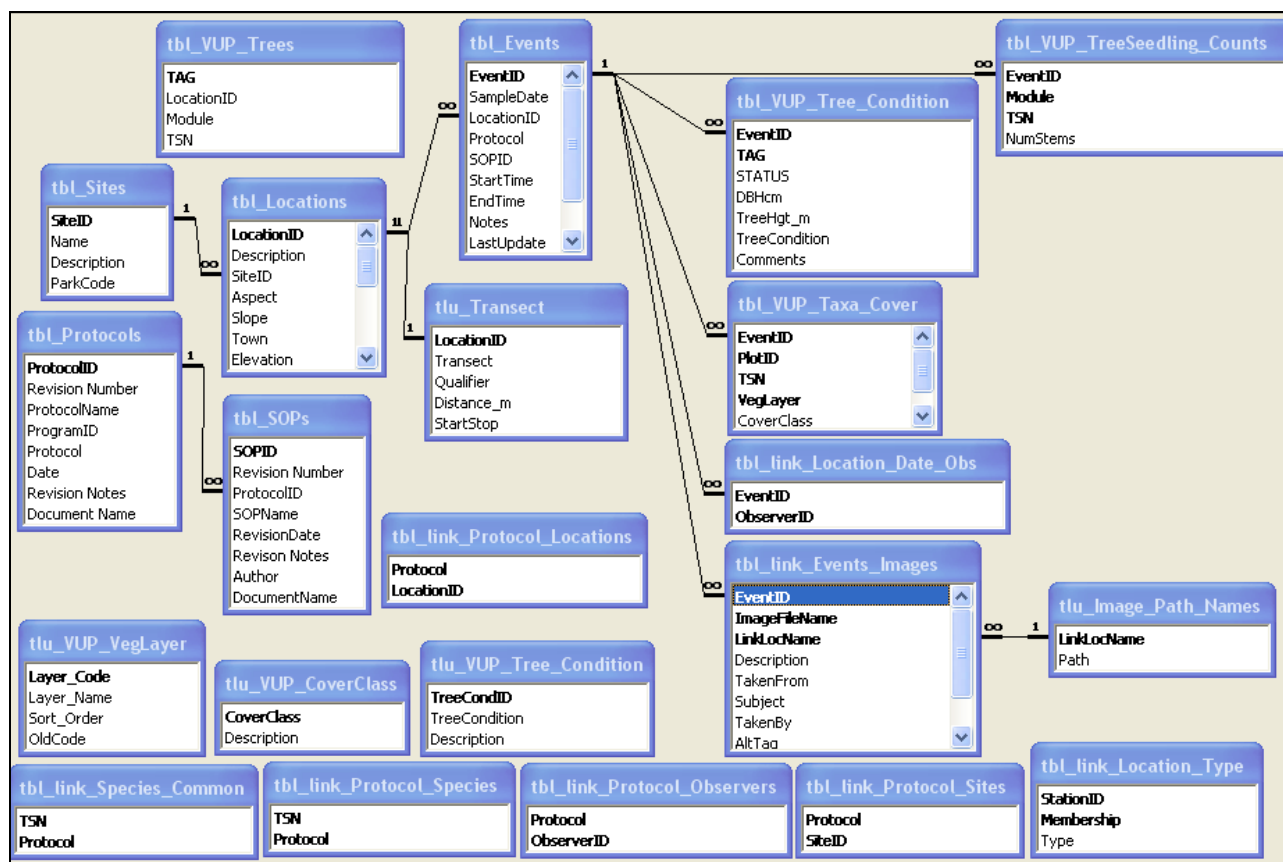
Figure 7.3 Coastal Forest Entity Relationship Diagram.

7.6 Coastal Forest Database Data Entry Screen

The data entry screen design for this database is relatively simple. The main form is built using just the event, location, and site tables. The SQL for the simple join used to create the main form is given in the Coastal Forest Database User's Guide. The SOPID (Standard Operating Procedure) field is hidden, since it will just be a database default of "VCF" at this time. If field procedures change in the future, the default value of the SOPID should change to associate the field procedures with the data. All of the tabs on the main form are directly from single tables linked on the EventID key except for the Trees tab and the Image tab. The Trees tab and the Plot Photos tab are made from simple joins of just two tables each. The queries used as the basis for these forms are also given in the Coastal Forest Database Guide.

7.7 Reporting and Exporting of Data to Other Applications

Reports and exporting facilities will be incorporated into the design over time. There are currently three menu items to export the basic information from each of the primary tables for tree condition, seedling counts, and taxa cover. This information can be used to verify data entry or for statistical analysis. The queries used to extract this information are typical joins that can be modified to create similar queries for getting segments of the data or just organizing the information in other ways. The queries used to create exported data from each of the three primary data tables are described in the Coastal Forest Monitoring Database Guide.

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7.8 Data Entry

A number of features have been designed into the database to minimize errors that occur when field data is transcribed to the database for storage and analysis. Forms are used for all data entry into the database without the need for direct access to tables (Figure 7.4). Standardized identifiers (e.g. locations, species, or plots) are selected from lists of easily interpreted codes. Look-up tables contain project-specific data and prohibit entry of data into a field if a corresponding value is not included in the look-up table. Consequently, only valid names, species, or measures may be entered. Some limits are set on measurement fields to help prevent errors. The Coastal Forest Data Dictionary lists limits on fields and describes the look-up tables used to restrict data entry.

Data entry should be completed as soon as possible after the field data is collected, generally within one week. If possible, the data entry should be done by one of the technicians who performed the field work so that the technician's memory will aid in the transcription process.

7.9 Data Entry Quality Control

While the goal of data entry is to achieve 100% correct entries, this is rarely accomplished. To minimize transcription errors, our policy is to verify 100% of records to their original source.

Figure 7.4 Basic Data Entry Screen.

Data entry will be done by one or two people. Each line of data should be checked by a second person. If no staff is available, the original technician should check 100% of the data entry on the following day. Once the computerized data are verified as accurately reflecting the original field data, the paper forms are archived and the electronic version is used for all subsequent calculations. The data entry will be checked more completely in the validation process.

7.10 Data Validation

Initial Database Design and Data Loading

Coastal forest data were collected over two calendar years (2002–2003) while the final protocol was being developed. This data was transcribed from the original field sheets into Microsoft Excel spreadsheets. The original spreadsheets were copied and information on the spreadsheets extracted in the order that was required for loading into the database. Site and location tables were populated first. All of the species and look-up tables were entered next. Referential integrity constraints were placed on all tables linking to the events tables to be sure that there were no orphaned records. Validation constraints on individual fields in the data table were applied wherever possible. Event information was extracted from the data and recorded on worksheet tabs on the copy of the original field data spreadsheet. EventID's were constructed in Excel by concatenating date, location, and standard operating procedure ID's. The event information was then imported from Excel to the database. Import errors were corrected when they occurred and the data were loaded a second time. Loading the event information first eliminated the possibility of having data that is in a table that cannot be accessed through a join with the events table. Integrity constraints on tables helped prevent importing inappropriate data entry in Excel into the database.

Data were loaded into each of the three primary data tables in sequence. EventID's were constructed in Excel as concatenated fields containing the park code, LocationID, Date, and standard operating procedure. Worksheet tabs were created for each table as they were imported to create a record linking the original data to the data imported to the database. Any import errors caused by errors in the original data entry (i.e. spelling errors) were corrected and the data re-loaded. The number of records imported was checked against the number of records in the original spreadsheet. Approximately 10% of the data in the database was checked by the field crew against the original spreadsheet information.

Validation of Data Entry

The data from each of the three primary tables were exported to Excel as a final validation check of the initial data loading. The original field sheets, Excel spreadsheets used to verify the initial data, and the original Access database have been archived for reference.

Spatial Data Validation

Maps and associated spatial information are considered part of the data. The monitoring database has a one-to-one relationship between locations identified in the database and the ARCInfo files.

Location information was exported from ARCInfo to the tbl_Locations of the monitoring database. Each location's coordinates and plot identification code were verified against the corresponding field in ArcInfo at the start of the project.

7.11 Database Administration

Database Revision Control

The database files will be controlled using a two-part revision numbering system. The first revision number will be included in the file name with the letter R followed by an integer. The revision number will also contain a decimal component that is used to indicate minor changes to the code or data entry screens. Each time there is a new monitoring period the revision number of the database will be increased. The primary revision number may also increase if there is a significant a change in the protocol or monitoring methods during a field season. The decimal component of the revision number (i.e. R2.04) does not have to be changed if a simple select query is added to the database. However, all changes to forms and reports should result in a change to the decimal component of the revision number. The addition of cross-tabulation, pivot table queries, or update or delete queries should also be noted on the revision history form and the decimal revision number of the database should be incremented. The decimal number would also be increased when data in a previous version of an archived database is altered. The decimal component will be indicated with an underscore in the file name. A typical database file name for this protocol might be CACO_Coastal_Forest_R2_04.mdb where the 04 represents that decimal part of the revision number. Revision histories can be viewed in the Database Revision History form and accessed through the About the Database form. In general, copies of the database should be made for analysis purposes, and queries that you wish to be made permanent should be added to the monitoring database with a corresponding change in the revision number of the monitoring database files.

Working Copies and Database Backup

Database files will be stored on the Park server in the appropriate I&M project folder. Individual backup copies of the data tables will be made frequently during the field season to prevent loss of information and to recover from data entry errors. The backup will be done using a database utility and will not require a name change or revision change to the database in use for the current field season. The backup files will be named after the original front end and data files with the current date at the end. Back-up copies are used for the current field season only and will not be archived.

Working copies of the database may be made but they should not be stored in the project folders. Only the current protocol database will be stored in the I&M project folder in order to prevent data entry errors. Working copies should be stored in staff directories and renamed to reflect the date at which the copy was made. Utility queries and reports added to working copies of a data base can only be imported to the current protocol database with the coordination of the Data Manager to maintain revision control of the protocol database.

7.12 Coastal Forest Data Set – Metadata and Cataloguing

Bibliographic information and FGDC-compliant metadata will be developed for this protocol so that the protocol documents, reports, and data are discoverable via public and park service bibliographies and clearinghouses. Preliminary notes for the development of metadata were developed using the Electronic Metadata Guide (developed by George Lienkaemper, USGS FRESC, Corvallis, OR). Procedures for the creation of metadata are being written at CACO referencing the Desktop Metadata Tools developed for NR-GIS data store. A preliminary text-based FDGC metadata record was created by entering information on the completed Metadata Guide into the National Park Service Inventory and Monitoring Dataset Catalog (Version 2002.1). The metadata file will be completed and validated using the Park Service Metadata Tools and Metadata Parser after the final version of the protocol is released.

The bibliographic information on this project will be added to NatureBib after final review of the protocol is complete.

7.13 Data Availability

This protocol, reports, data, the database guide, data dictionary, and all other data products will be available directly from CACO. Data can also be transferred using e-mail or ftp where available. Additional public electronic archives are planned out of the Fort Collins office in the near future. Requests for data and reports before they are published on a CACO I&M website should be directed to:

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Standard Operating Procedure (SOP) #8. Preparations and Equipment Storage at the Conclusion of the Field Season.

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #8
Preparations and Equipment Storage at the Conclusion of the Field Season

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

At the end of the field season, it is imperative that all equipment be inventoried, repaired (or replaced) if necessary, and stored in its proper location. The data and resulting products (e.g., reports) should also be organized and archived. To accomplish this, the field crew should follow these steps:

1. Compile, clean, and return all equipment to its proper storage place
2. Clean the assigned vehicle and make sure it is left with a full tank of gas and sufficient oil.
3. Organize and photocopy all field datasheets and notes. Give all data to project manager for safekeeping
4. Make sure all data has been entered into the electronic database and saved in the proper folder on the NACL server
5. Complete end-of-season report

Standard Operating Procedure (SOP) #9. Coastal forest monitoring safety.

Cape Cod National Seashore
Coastal Forest Monitoring Protocol
Standard Operating Procedure #9
Coastal Forest Monitoring Safety

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

In addition to the basic requirements of the programmatic SOP, the following safety measures will be implemented as part of the Coastal Forest Monitoring Protocol:

-the project manager will encourage field staff to use insect repellent on their clothes;
-the project manager will provide light-colored coveralls if desired by field staff;
-field staff are encouraged to perform periodic tick checks while in the field;
-the project manager will ensure adequate poison ivy pre-contact solution (such as Ivy Block) and post-contact wash (such as Technu™) is available for the duration of the field season.

In addition, all project staff are encouraged to recommend changes or additions to the programmatic safety SOP.

Appendix A. Selected comparisons of variable-radius vs. fixed-area plot data.

Tree basal area was calculated from the 2002 angle-gauge data within variable-radius plots (VRP) using standard equations of forest mensuration (Husch et al. 1993). These were compared to the 2002 modular plot data. A perfect representation of species-specific Basal Area within the fire stake network by the modules would correspond to a R^2 value of 1.0.
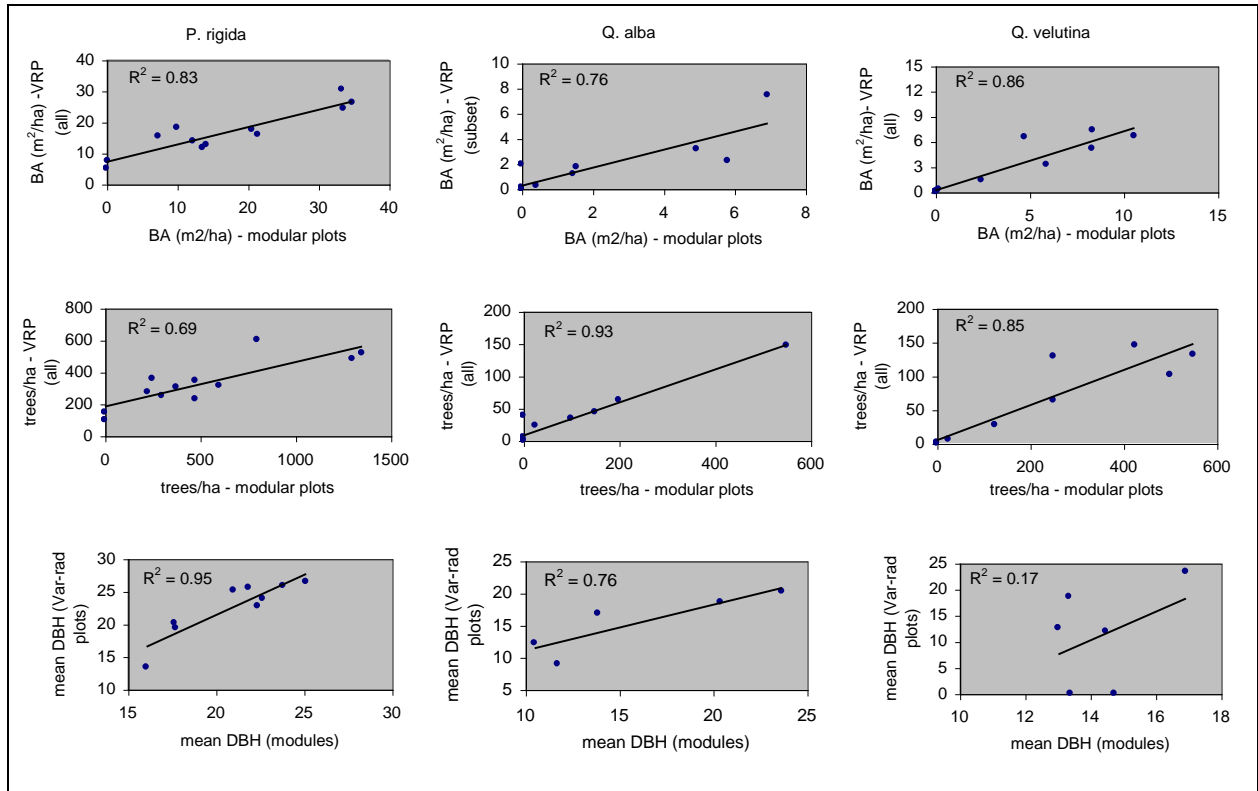
Appendix B. Site descriptions and locations.

		UTM (zone 19T)	
		Northing	Easting
Site ID	Forest Type		
CC01	Beech	4658315	400811
CC02	Pitch Pine	4644126	411378
CC03	Pitch Pine-Black/White Oak	4648382	413642
CC05	Pitch Pine-Black/White Oak	4648086	411987
CC06	Pitch Pine-Black/White Oak	4637455	419084
CC07	Pitch Pine	4656120	408766
CC08	Black/White Oak	4652177	412979
CC09	Pitch Pine-Black/White Oak	4648374	414857
CC11	Pitch Pine-heathland	4639186	419136
CC12	Pitch Pine-heathland	4658146	399486
CC13	Pitch Pine	4645686	413687
CC14	Pitch Pine-Black/White Oak	4645725	413575
CC15	Pitch Pine-Black/White Oak	4647977	414371
CC16	Pitch Pine-Black/White Oak	4647978	414344
CC17	Pitch Pine	4656153	409182
CC18	Red Maple	4656642	399248
CC19	Red Maple	4646207	416231
CC20	Red Maple	4646077	414945
CC21	Red Maple	4640511	418536
CC22	Red Maple	4630391	419792
CC23	Black/White Oak	4654391	411119
CC24	Black/White Oak	4653121	412039
CC25	Black/White Oak	4648560	413338
CC26	Black/White Oak	4646796	415233
CC28	Atlantic White Cedar	4640485	418594
CC29	Atlantic White Cedar	4640367	418583
CC30	Pitch Pine	4633842	420380
CC31	Pitch Pine-heathland	4650795	414340
CC32	Pitch Pine-heathland	4643819	411152
CC33	Pitch Pine-heathland	4639127	419257
CC34	Black Locust	4644906	415542
CC35	Black Locust	4648742	412636
CC36	Black Locust	4645683	413259
CC37	Black Locust	4648661	413902
CC38	Black Locust	4633256	420024
CC39	Beech	4658202	401037
CC40	Beech	4658279	400767
CC41	Beech	4658480	400556
CC42	Beech	4658434	400619

Forest type	2000 acres	% total CACO area
Atlantic white cedar	11	0.04%
beech	69	0.27%
black locust	143	0.55%
red maple	533	2.05%
oak (black and white	2,460	9.44%
pitch pine	5,093	19.55%
pitch pine - oak	5,517	21.18%
CACO	26,047	

Site maps and information

The following sites originally established by Patterson et al. (1983) have not been re-located or re-sampled:

CC04 - This site was converted into an experimental research site by Bill Patterson in 1984.

CC10 - This site could not be re-located.

CC18 - This site is a dead Scots Pine plantation in the Province Lands that has not been re-located since 1981. The new CC18 is now a red maple site.

CC01

Directions: Take Rt. 6E to Race Point Rd. and go right on Race Point Rd. Drive to the Province Lands visitor center to turn around, and backtrack on Race Point Rd. for approximately 0.3 mi. Park immediately after the first "Speed Limit 30 mph" sign. The site is upslope and to the right about 300 feet away.

Fire stakes: 24 stakes, A through X.

Module orientation: Linear-contiguous; N–S bearing for modules = 20º; oriented around stake D. Canopy photos in center of boundary line between modules 2 and 3.
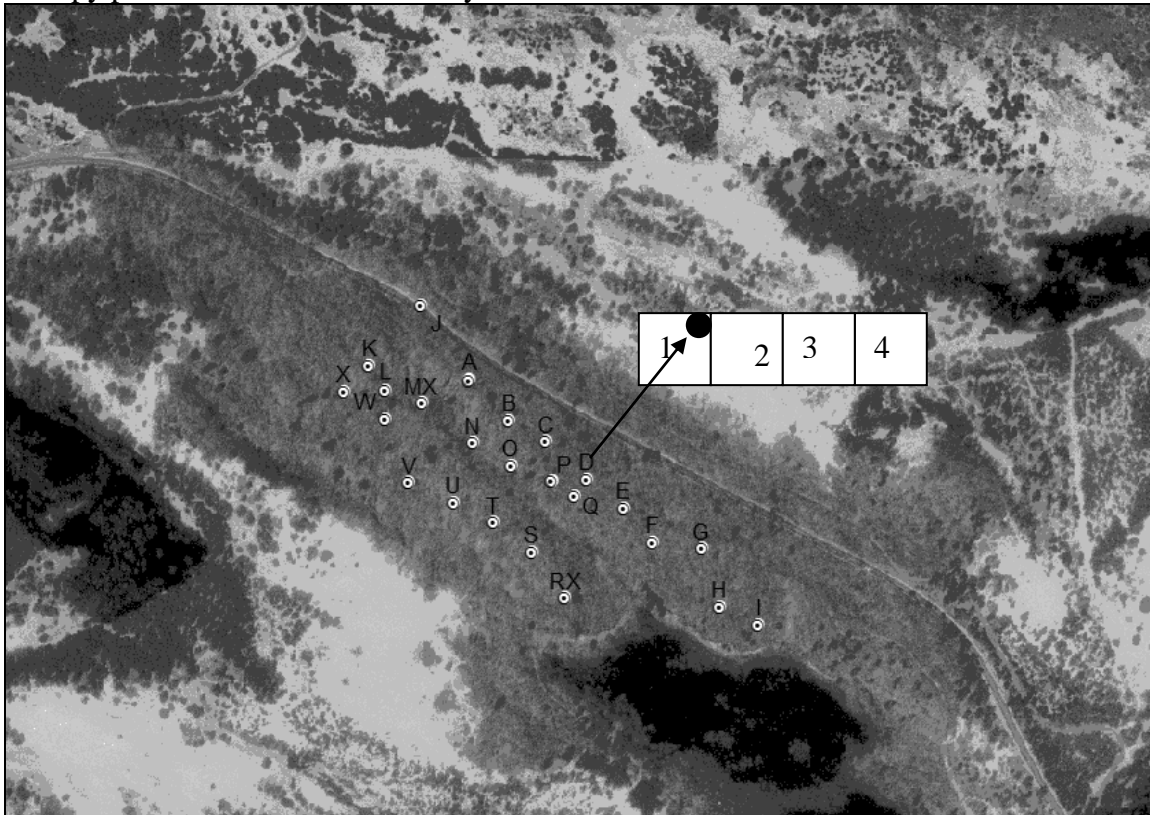
<u>CC02</u>

Directions: Take Rt. 6W. Just after Moby Dick's restaurant turn right onto Briar Lane at the blinking yellow light across from the Outer Cape Health Service. Follow this road to stop sign in Wellfleet center. Go straight across the intersection onto Holbrook Lane. Take the first right onto Chequessett Neck Rd. At fork in the road stay left on Chequessett Neck. At the end of the road there is a stop sign, bear right. Follow the road across bridge, towards the paved Great Island parking lot. At the triangle follow the signs for Duck Harbor, bearing right. Follow the road almost to end and turn around on a small dirt pull-off (the beginning of a fire road). Backtrack to park on the right at a small pull-off opposite of the "Kuhn" driveway, a small dirt road. Follow the dirt road back about 500 feet or so, where you can cut in on a small deer path/opening in the heath.

Fire stakes: 46 stakes, A–Z and AA–AU in two long transects

Modules: Four-square. N–S bearing for modules = 0°. Oriented around stake G. Canopy photos at stake G.
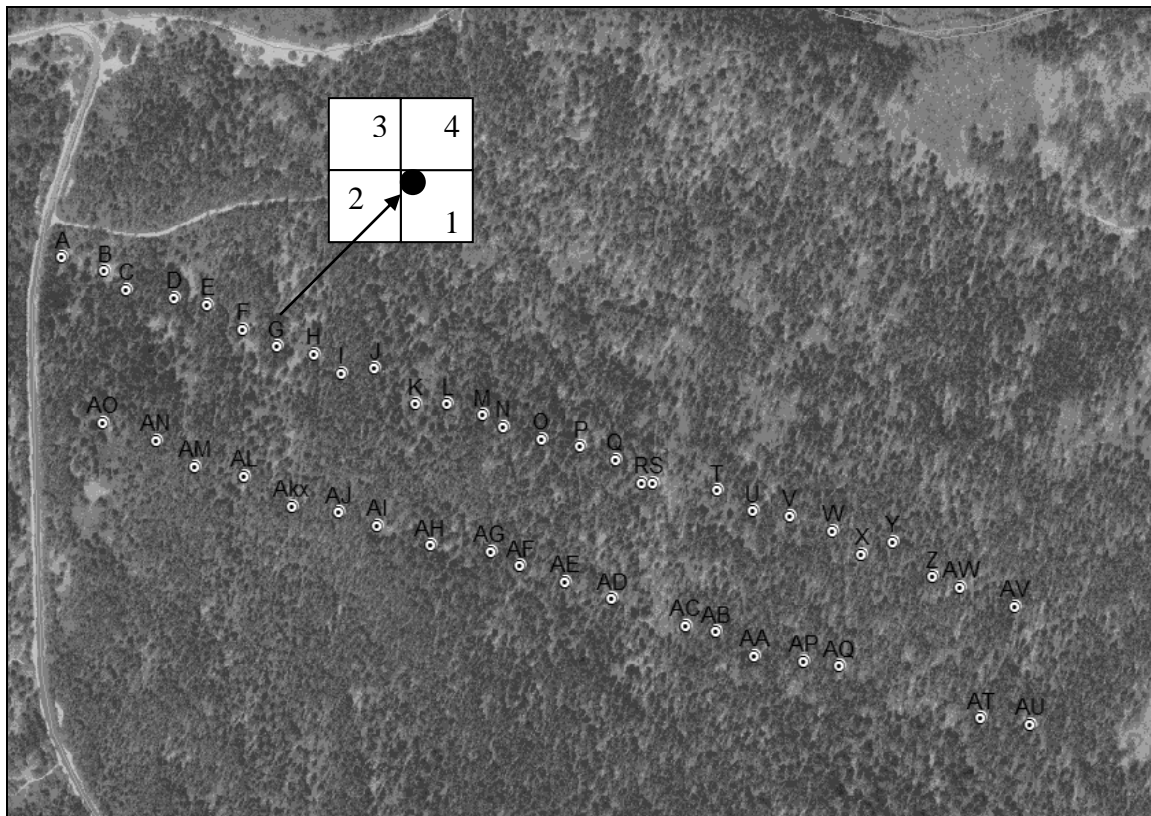
Directions: Take 6W past the Truro transfer station. Just after that, turn around at the old gas station that sells firewood. Backtrack on 6 past the transfer station sign and park just before the "trucks turning right" sign. Walk up the old paved path and the first two modules are back to the right. :

Fire stakes: 24 stakes, A through X

Modules: Separate two-squares. N–S bearing for modules = 0º. Modules 1 and 2 oriented around stake G. Modules 3 and 4 oriented around stake P. Canopy photos in center of boundary line between modules 2 and 3.

Directions: Take Rt. 6 W to the Pamet Rd. exit. Take the first left after the exit onto Depot Rd. Follow Depot Rd. bearing left at the split onto Old County Rd. Follow Old County Rd. (bearing left at another split) for a mile or two until you come to a dirt road with a sign for Pine Grove Cemetery. Turn left here and proceed down the main dirt road until you see the cemetery on the left. At this point, turn left and stay on this lesser maintained road. Eventually you will come to a little fork in the road which is actually two ends of a loop. Take the left one (park in the middle of the loop). When leaving, continue out the other way.

Fire stakes: 36 stakes, several of which are difficult to locate, even with the assistance of the GPS.

Modules: Four-square. N–S bearing for modules = 0º. Oriented around stake AC. Canopy photos in center of boundary line between modules 1 and 2 and between 3 and 4.
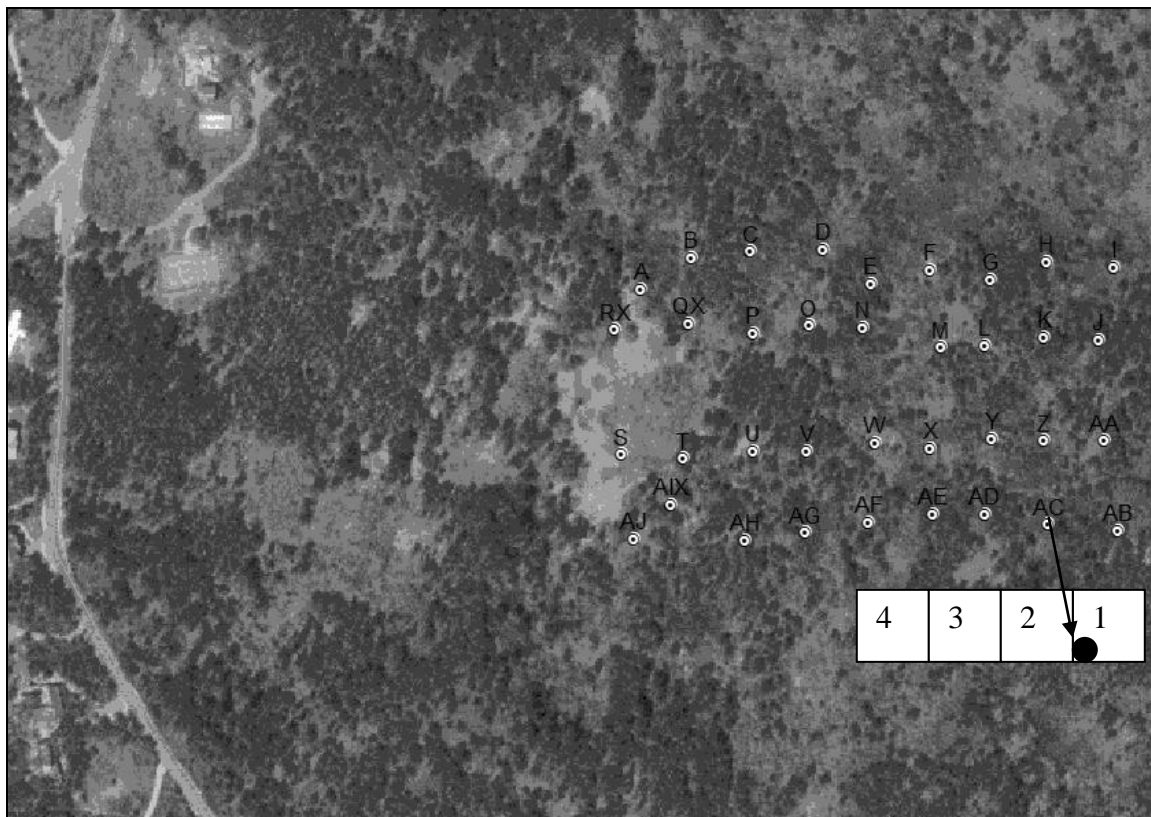
CC06

Directions: Take Rt. 6W to the entrance to Marconi Site/Headquarters. Follow the road to Marconi beach, and turn right on the first fire road. Follow the fire road a mile or two. At the second road to the right, turn around so you can park facing out. The site is in the woods to the right if you are on that side road facing the main road (facing north). The easiest way to get to the stake where the modules are is to follow that side road down ~ 300 ft. and cut in where the pines start to thin out.

Fire stakes: There are 20 stakes at this site, C through H, and J through W.

Modules: Four-square, N–S bearing for modules = 0°, oriented around stake K. Canopy photos at stake K.
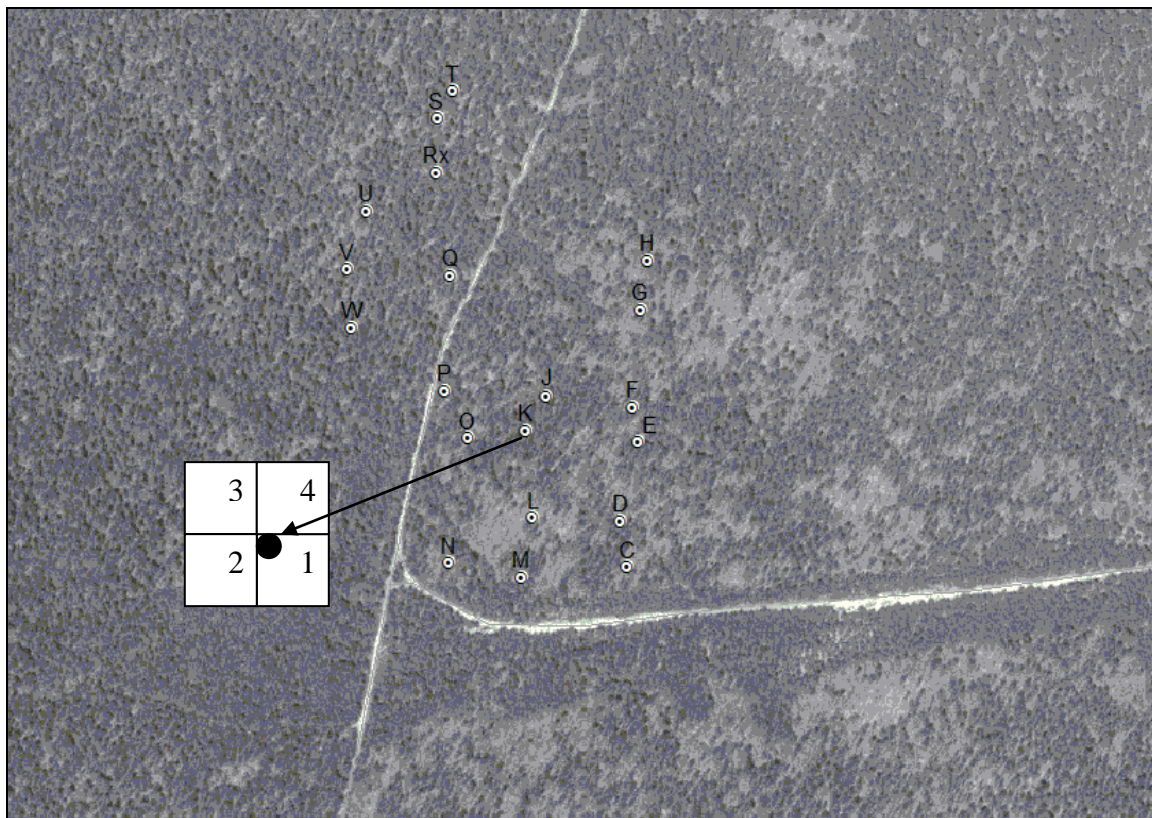
<u>CC07</u>

Directions: Take Rt. 6E to Pilgrim Heights. Park at the end of the second parking area (around the loop). Take an unmarked footpath from the corner of the parking lot in to the path under the power lines. Turn right at the power line and walk a little ways into a small depression. Turn left into the woods at an angle and the site is about 0.1 mi. away.

Fire stakes: 38 stakes, A to AL.

Modules: Four-square, N–S bearing for modules = 0º, oriented around stake AK. Canopy photos at stake AK.
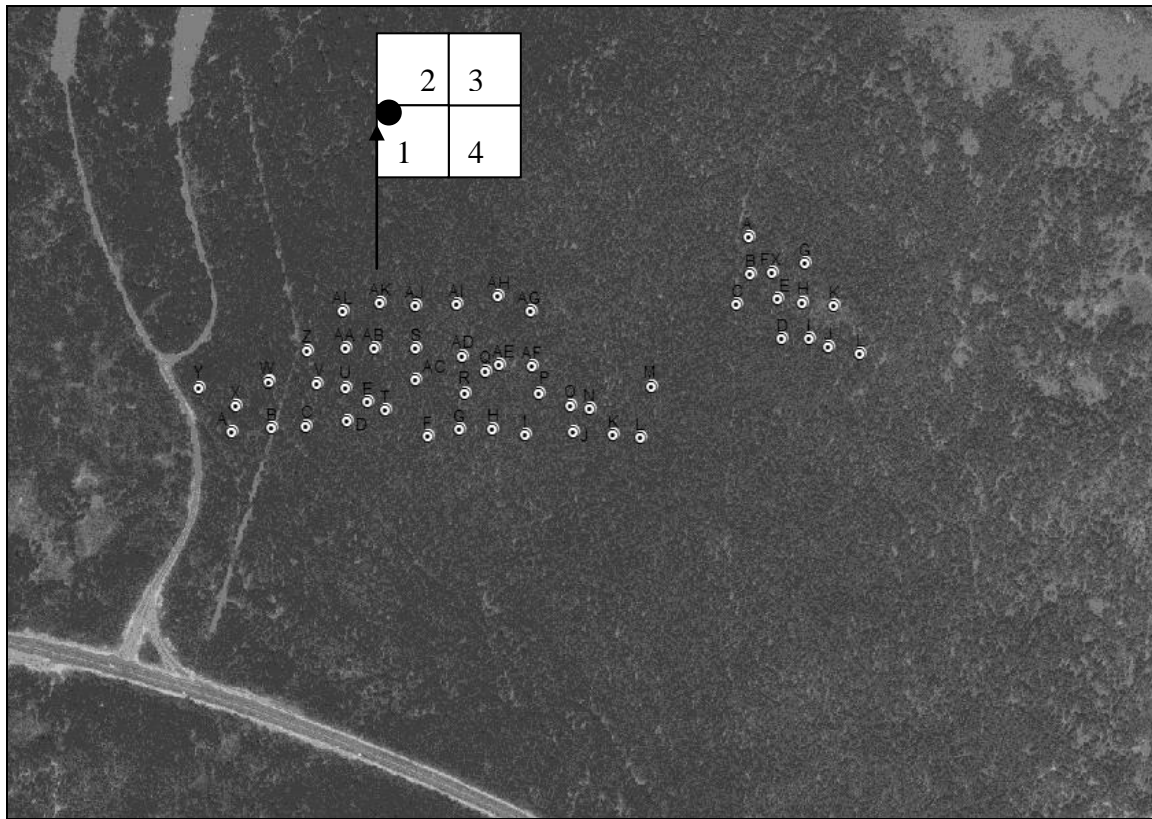
Directions: Leaving the lab, take a left onto the dirt road off of Dewline Rd., which is Old King's Highway. Follow this dirt road about 1.3 mi., being careful for bikers/walkers etc. (I've seen more on this road than most). Park in a pullout on the left side of the road where the road takes a right turn. Walk about 500 ft to where a slight bend in the road makes the truck barely visible, and the site is in on the right about 200 ft.

Fire stakes: 29 stakes,

Modules: Four-square, N–S bearing for modules = 0°, oriented around stake T. Canopy photos at stake T.
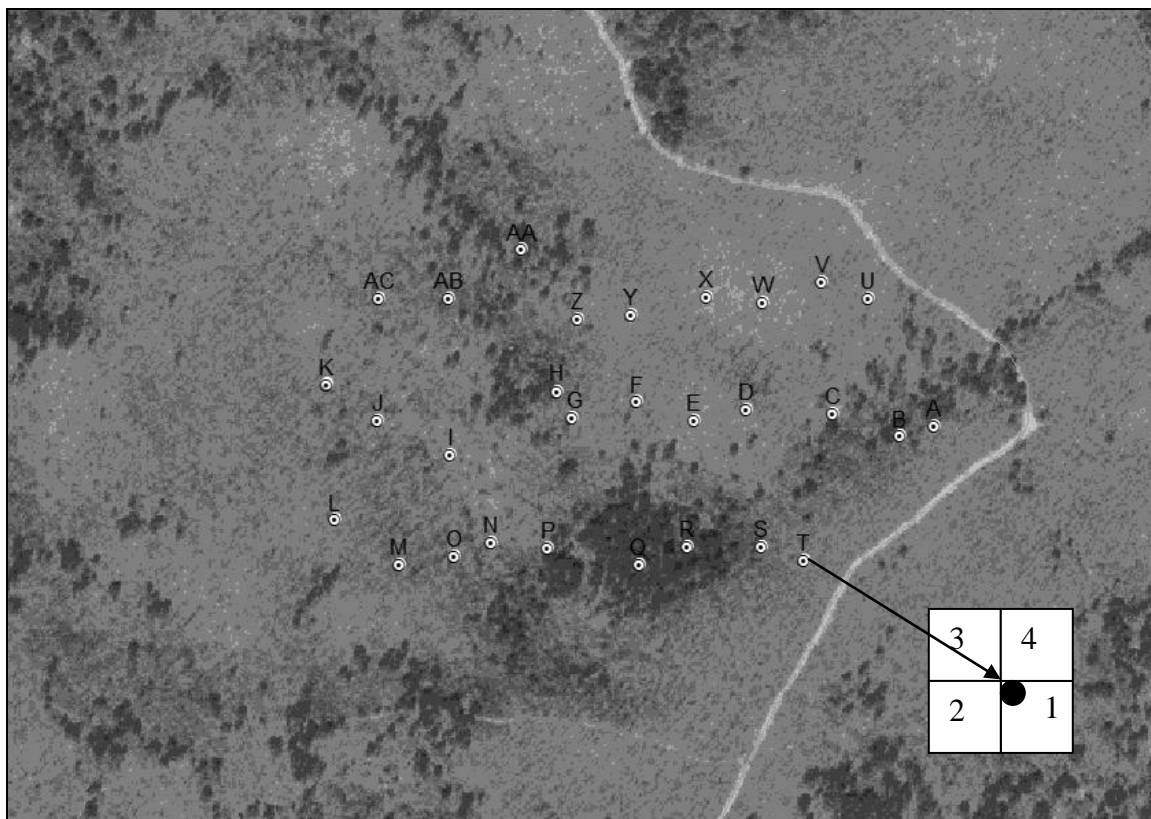
<u>CC09</u>

Directions: Take Rt. 6W to the South Pamet Rd. exit. Taking that exit, follow the road to your first right, going under the route 6 bridge. Follow the road until it takes a left turn, and at that point you want to take a right turn onto Collins Rd. Go approximately 0.8 mi. to park at a sandy pullout on the left, a little before the fire road to CC15 and CC16. Take the path from the pullout. When the path splits take the right trail, go upslope and at a sandy eroding patch, go right again. Go about another 100 ft. and the site will be in on the left just a little bit, with the stake being in an open area at the base of a little slope.

Fire stakes: 27 stakes, A through AA.

Modules: Four-square. N–S bearing for modules = 0º. Oriented around stake W. Canopy photos at stake W.
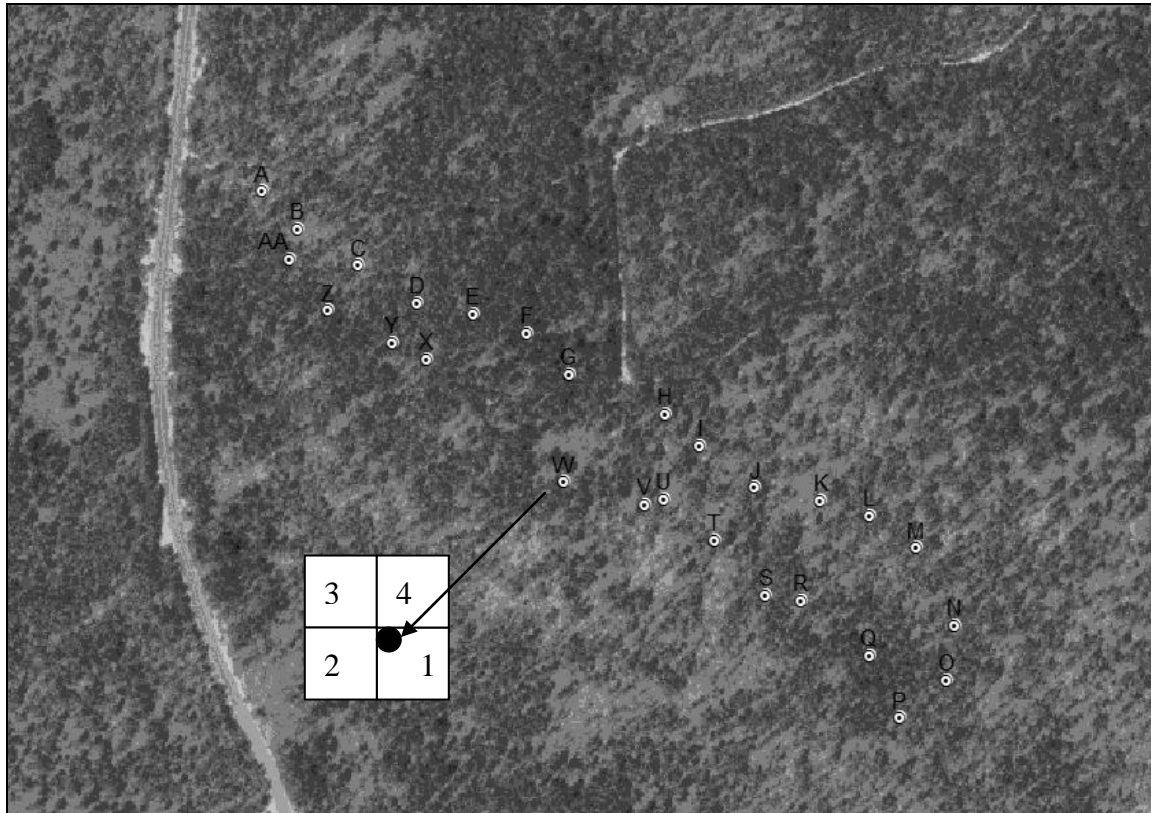
CC11

Directions: From the lab take Rt. 6W to Headquarters. Drive past headquarters, through the open gate and there's an access road on the right, turn right. Drive to the end of the road and park the truck. If you are facing the woods at the end of the road the site is in on the left

Fire stakes: 26 stakes in two transects, A to Z

Modules: Four-square. N–S bearing for modules = 0º. Oriented around stake D. Canopy photos at stake D.
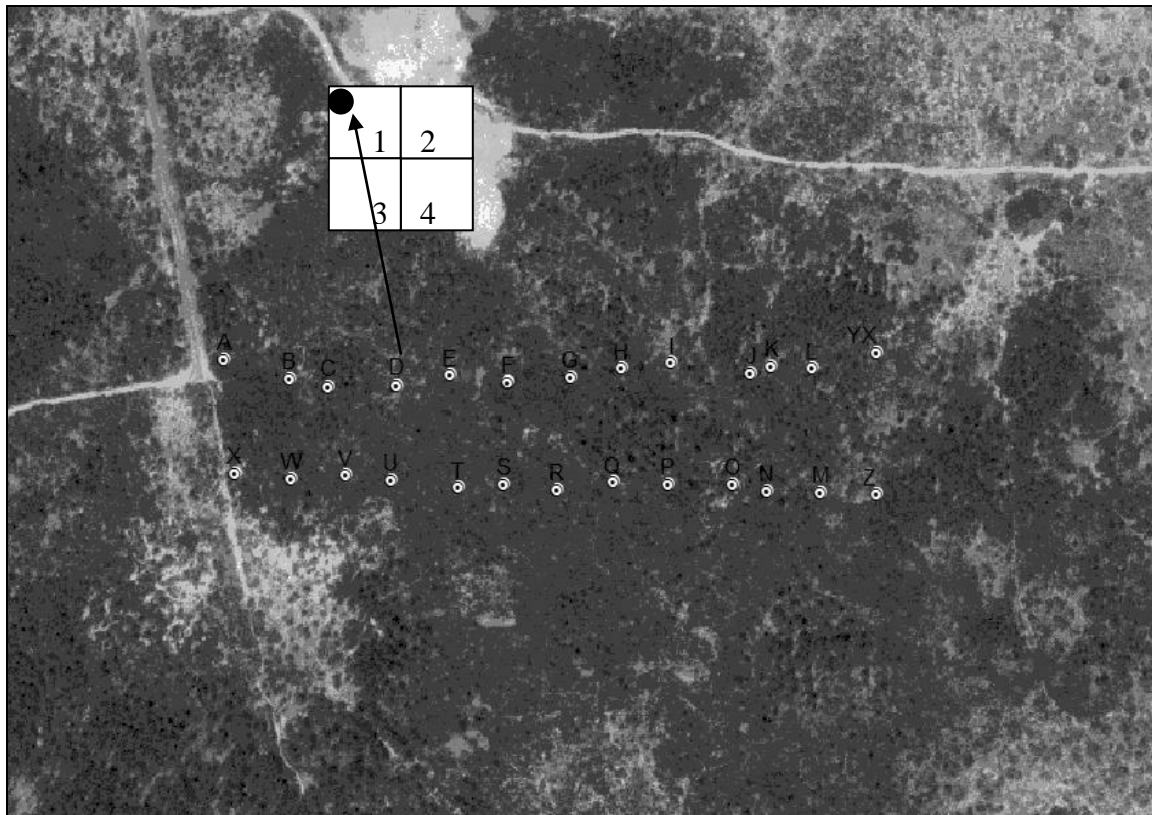
Directions: Take Rt. 6E until you get to the set of lights to take a right turn onto Race Point Rd. Drive past the Province Lands Visitor's Center and take the left turn to go to Herring Cove. The parking lot is 0.4 mi. down on the right side. The site is down the dune in the pitch pine.

Fire stakes: 24 stakes in two transects, A to L and O to Z

Modules: Separate two-squares. N–S bearing for modules = 0º. Modules 1 and 2 oriented around stake O; modules 3 and 4 oriented around stake P. Canopy photos at stake O.
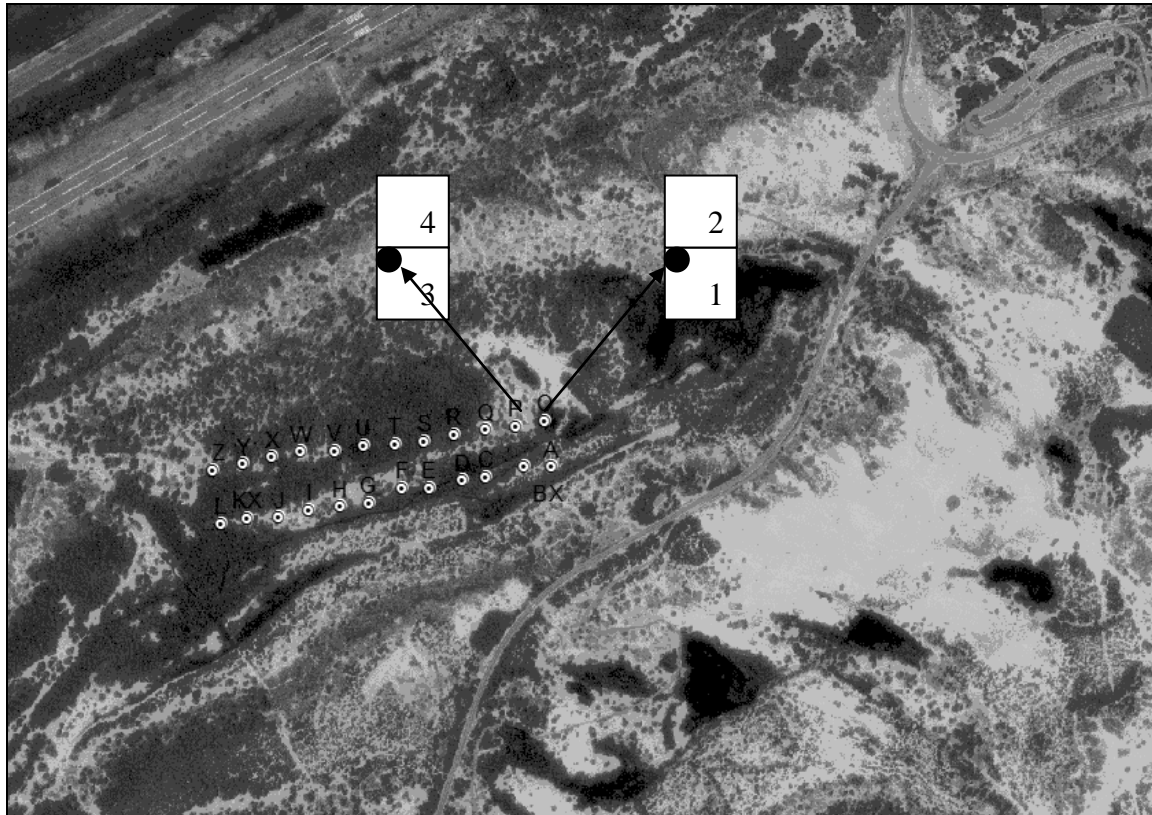
<u>CC13</u>

Directions: Take 6W. Just past the Welcome to Wellfleet sign take your first right onto Pamet Point Rd. (at the sign for the Atwood Higgins house). Follow the road to the end to turn around the little island and backtrack 0.5 mi. You pass the little stand selling flowers from someone's garden, and then there will be a black locust stand on the right (at a slightly lower elevation than the road). Park at the third power line pole at the end of the black locust stand. If you're looking for it, you'll see a small pullout that we've made from parking there. CC13 is on the top of the ridge on your right.

Fire stakes: 24 stakes, A through X that are in a line straight down the ridge.

Modules: Four-square. N–S bearing for modules = 0°. Oriented around stake L. Canopy photos at stake L.
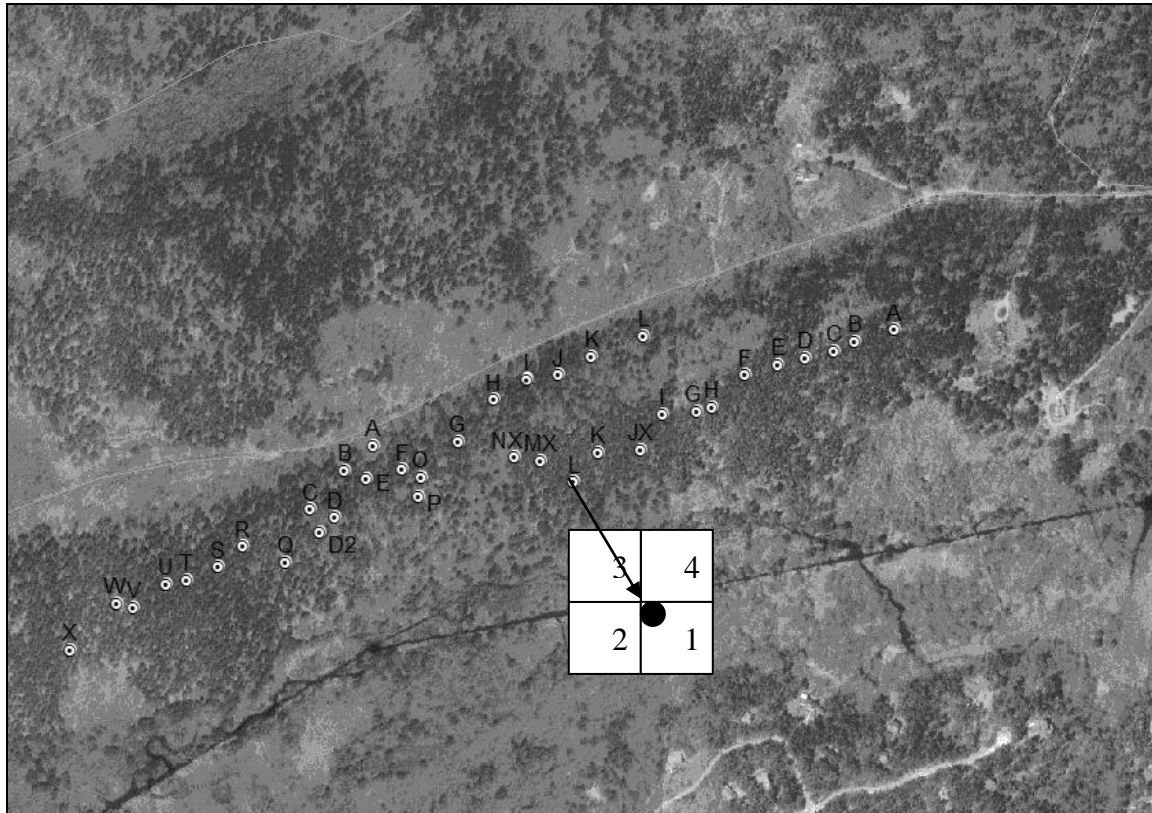
CC14

Directions: See CC13 directions above

Fire stakes: Stakes C and D are both in a small ravine going down slope. Because of this, a second D was installed at some point called 'D' on the original map and D2 in the GPS in 2001. This point was most likely installed because it goes away from the ravine and back into *Gaylussacia*, which is more consistent with the rest of the site and less influenced by drainage patterns. D2 was located in 2001, but no data was collected.

Modules: Separate two-squares. N–S bearing for modules = 330º. The first two modules are oriented around stake G, three and four are oriented around stake H. No canopy photos acquired here.
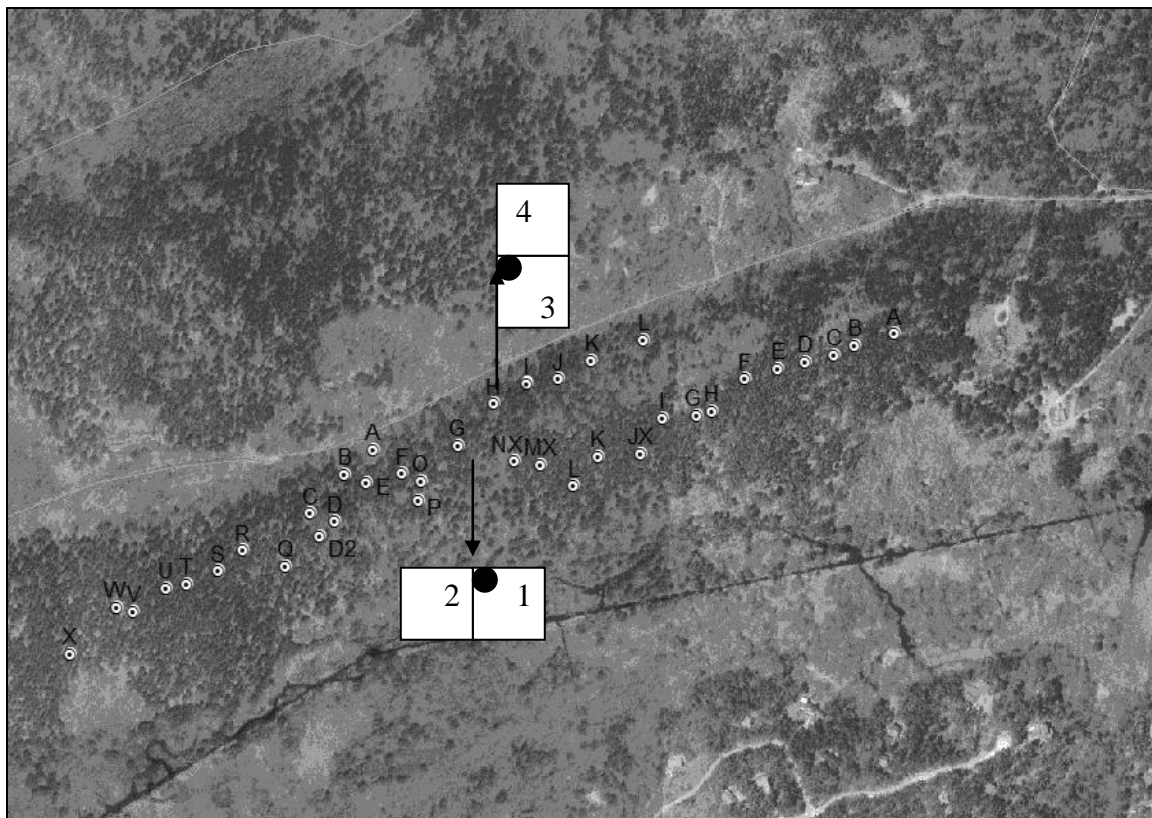
CC15

Directions: Follow the directions to CC09, continuing on Collins Rd. to Firegate #2. Pass through the fire gate and follow the road until it ends in a T. Park the car there. CC15 is in the thick vegetation you just drove through.

Fire stakes: 10 stakes here labeled A through J. The stakes here are only 35 feet from eachother, or just over ½ a chain, as opposed to the standard 100 ft. or 2 chains.

Modules: All modules separate. N–S bearing for modules = 0º. Module 1 oriented around stake E and encompasses stake D. Module 2 oriented around stake A and encompasses stake B. Module 3 oriented around stake F and partially encompasses stake G. Module 4 is oriented around stake J. No canopy photos acquired here.

CC16

Directions: See directions to CC15.

Fire stakes: 20 stakes for this site work their way around CC15 in somewhat of a boot formation.

Modules: One two-square and two individual modules. N–S bearing for modules = 0°. Modules 1 and 2 are oriented around stake A. Module 3 is oriented around stake S. Module 4 is oriented around stake N. Canopy photos in center of boundary line between modules 1 and 2.

CC17

Directions: Take Rt. 6E towards Provincetown. Just past Montano's restaurant go right into the second driveway (it's difficult to see the first few times), #489. There's an old fire road at the end of the driveway with a fence in front of it to prevent vehicle access. Walk down this road about 0.13 mi. The site is off to the right less than 200 ft from the road off stake Fx. When walking out be careful not to walk right past the fire road. It is fairly overgrown and can easily be missed.

Fire stakes: 12 stakes

Modules: Four-square. N–S bearing for modules = 0º. Oriented around stake Fx. Canopy photos at stake Fx.
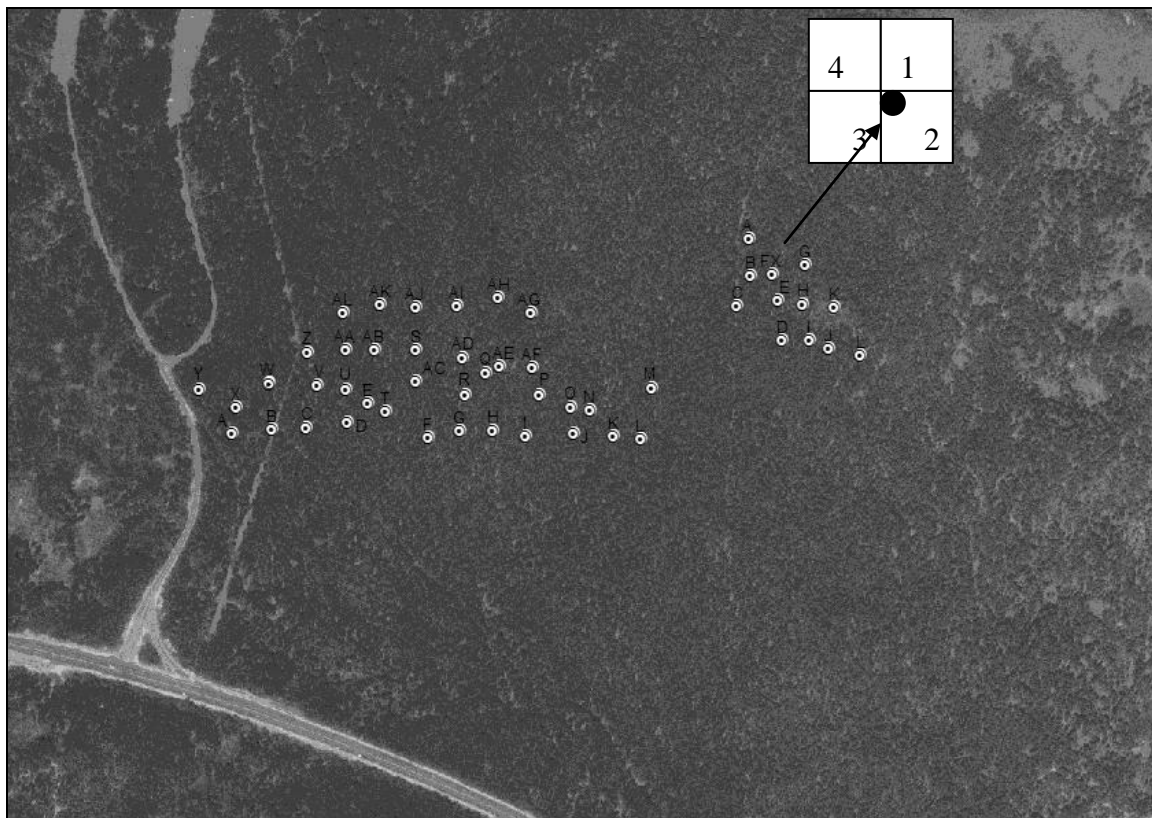
CC18

*Directions***:** From NACL, take Route 6 east toward Provincetown. Once in Provincetown, follow Route 6 and take a right onto Provincelands Road toward Herring Cove. Park at the pull-off on the right side of the road directly after the first fire road. The site is directly across the road.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC19

Directions: From NACL, take Route 6 west toward Wellfleet. Turn Right onto Gull Pond Rd (across from Moby Dick's Restaurant). Turn right onto Gull Pond Landing (marked by white granite stone sign). At Gull Pond parking lot sign, follow the dirt road left. Stay on the dirt road to the left of the first fork in the road and go past Herring Pond sign and past residence 460 "Fromb". Park at the pull-off on the left just over the small creek. The plot is on the west side of the creek (best way to access is to wade in the creek for ~50 feet then up the left bank).

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC20

Directions: From NACL, take Route 6 west toward Wellfleet. After the "Entering Wellfleet" sign on the left side of Route 6 and after passing one set of metal guardrails, turn left onto a dirt road. This turn is between the end of the first set of guardrails and at the beginning of another set. Drive down this road and park at the first dirt pull off on the left side of the road.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC21

Directions: From NACL, take Route 6 west toward Wellfleet. Take a left onto LeCount Hollow Road. Take a right onto dirt road marked by a small post saying, "wireless station route." Go through the fire gate and bear right at the first Y in the road. Drive to the end of the road and turn around and then park at pull-off on the left side of the road opposite marking flag and "No Hunting" sign. The plot is 200 meters into the woods.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC22

Directions: From NACL, take Route 6 west toward Eastham. Once in Eastham, turn left off route 6 onto Hemenway Road. Turn around in the boat launch parking lot and park on the right-hand side of the road. Walk the red maple boardwalk and when you come to a "Y," veer left. The site is at the end of this section of boardwalk.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC23

Directions: From NACL, take the first fire road off Highland Road (North) until the first intersection where the truck should be parked. Hike 250 feet back down the road and then turn West and walk 100 feet into the woods.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC24

Directions: Drive 0.4 miles on Old King's Highway and take the first right. Park at the entrance to this dirt road. Walk ~280 feet west down the road, then turn north and walk ~40 feet into the woods.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

<u>CC26</u>

Directions: From NACL, take Route 6 west. Take a right toward Truro center and go under the bridge and turn onto North Pamet Road. Take a right into Collins Road from North Pamet Road. After passing parking spaces for the pond, there will be a dirt road on the left side of the road. Go immediately around a sharp turn and park at the pull-off directly following. Walk up the dirt road across the street approximately 200 feet and then into the woods (east) approximately 90 feet.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

<u>CC28, 29</u>

Directions: From NACL, take Route 6 west toward Wellfleet. Turn left at Marconi Station (Seashore headquarters). Take the first left toward maintenance and follow toward back left dumpsters. You will find a dirt road on the right that will lead you into the Atlantic White Cedar Nature Trails. Stay to the right and park on the left directly after the trail leading to the cedar swamp. Follow the boardwalk and take the first left. The plots are on the left (west) side of the boardwalk.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center
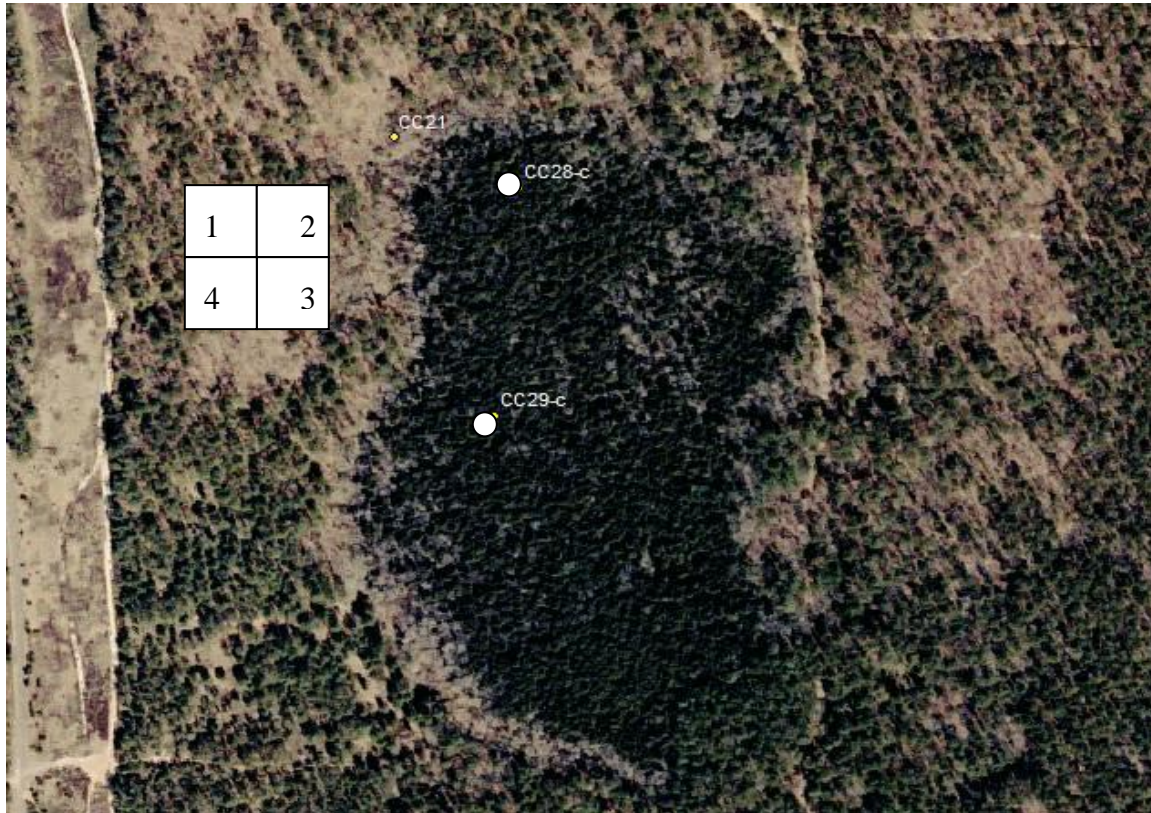
CC30

Directions: From NACL, take Route 6 West. Once in Eastham, go left onto Doane Road at the set of lights by the Salt Pond Visitors Center. Take a left onto Nauset Road. Drive until a Ranger Station is visible on the right side of the road. Turn at the next right, which is a fire road and drive ~0.4 miles up the fire road. At the Y in the road, veer left. Drive another 200 feet and park on the side of the road. The plot is 50 feet west into the woods.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

<u>CC31</u>

Directions: Take Route 6 south to N. Pamet Road. Follow North Pamet Road until it ends. Turn around and take the second right, which is Old King's Highway. Follow Old King's Highway 0.2 miles and park at or across the driveway of 18 Old King's Highway. Walk 232 feet south on Old King's Highway and then 20 feet east to the plot.
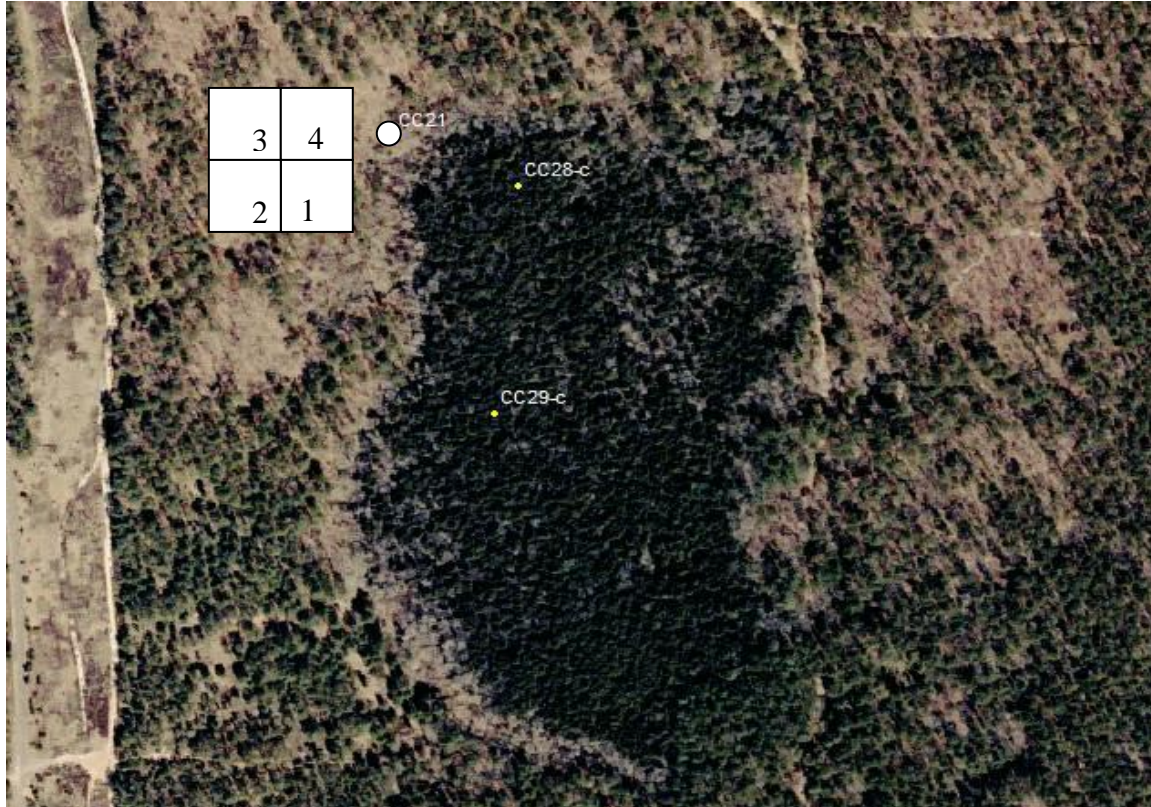
Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC32

Directions: From NACL, take Route 6 west toward Wellfleet. Just after Moby Dick's restaurant turn right onto Brian Lane at the blinking yellow light across from the Outer Cape Health Service. Follow this road to the stop sign in Wellfleet center. Go straight across the intersection into Holbrook Ln. Take the first right onto Chequessett Neck Rd. At the fork in the road, stay left on Chequessett Neck. At the end of the road there is a stop sign, bear right. Follow the road across the bridge, toward the paved Great Island parking lot. At the triangle, follow the signs for Duck Harbor, bearing right. Follow the road almost to end and turn around on a small dirt pull-off (the beginning of a fire road). Backtrack to park on the right at a small pull-off opposite of the "Kuhn" driveway, a small dirt road. See map below for directions to site.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC33

Directions: From NACL, take Route 6 west toward Wellfleet. Take a left off Route 6 at the turn for headquarters in South Wellfleet. After passing the main headquarters parking lot, take the first right-hand turn. Drive to the end of the paved portion of this road and park.

Modules: Four-square. N–S bearing for modules = 0°, Canopy photos from center

CC34

Directions: From NACL, take Route 6 west toward Wellfleet. Turn left onto Gull Pond Road (directly across from Moby Dick's Restaurant). Drive approximately ½ mile and turn left at the green mailbox marked "Portnoy 403." Follow dirt road to second left and loop left to park at the entrance of the powerline station. Walk east into the woods and you will be in the black locust stand.
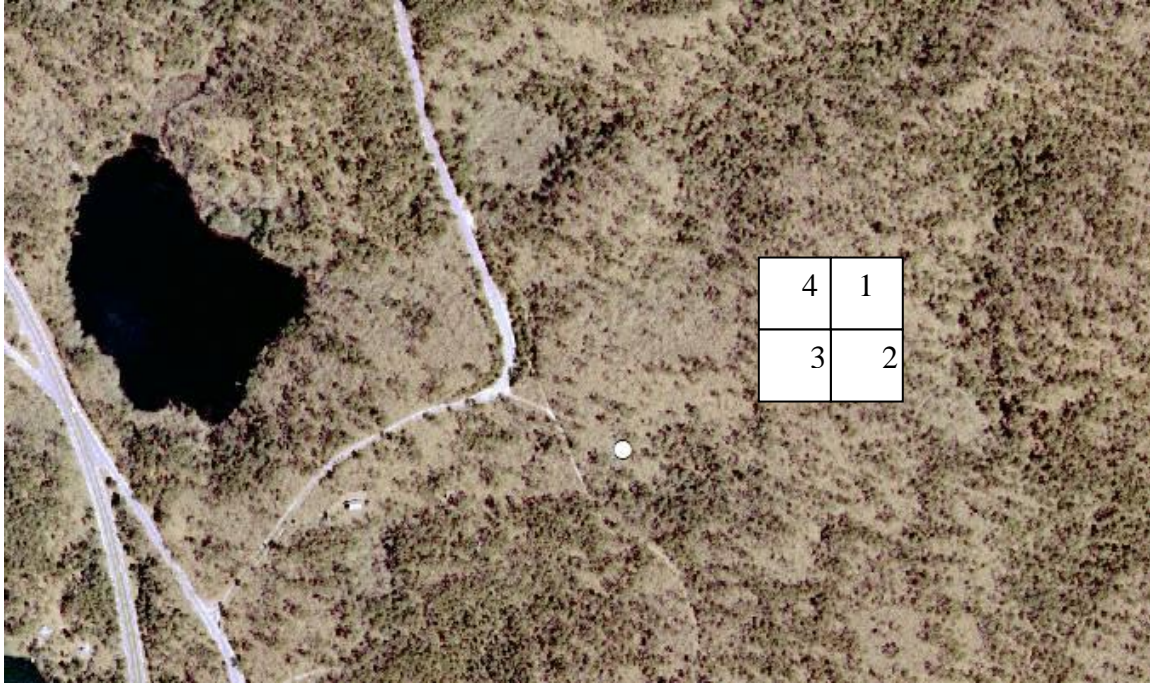
Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC35

Directions: From NACL, take Route 6 west toward the Pamet Road exit. Take this right-hand turn and take a left onto Old County Road. Keep left at the Y in the road and take a left onto Holsberry Road. Follow this road until it ends and take a sharp left onto a dirt road. Park at the second pull off on the right. Walk up the road 100 meters further, turn 90 degrees, and the site is directly at the top of the hill.

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC36

Directions: From NACL, take Route 6 west toward Wellfleet. Turn right onto Pamet Point Road (right after "Now Entering Wellfleet" sign), towards Atwood Higgins House. Follow road to end and turn around at circle. Go back approximately a ¼ mile and park right past the first house on the left. The plot is next to a 6 inch stone wall opposite this house.

Modules: Offset from 1 and 3. N–S bearing for modules = 0º, Canopy photos from center of boundary between 1,4 and 3,2 (2 images).

Directions: From NACL, take Route 6 west toward Wellfleet. Take the South Pamet Road exit off Route 6 and travel on this road past Misty Hollow Road. Turn right at the sign that says #41 Falk and Piecuch. Travel this road until you see a fire road on the left-hand side. Turn onto this fire road (#6) and drive, keeping left, until the pull off with two blue marking posts (park here).

Modules: Four-square. N–S bearing for modules = 0º, Canopy photos from center

CC38

Directions: From NACL, take Route 6 west toward Eastham. Once in Eastham, turn left off route 6 onto Nauset Road. Look for the South District Ranger Station on the left side of the road and when located, pull into the parking lot and park here. The plot is in back of the Ranger Station

Modules: "T"-shaped layout. N–S bearing for modules = 0º, Canopy photos from center
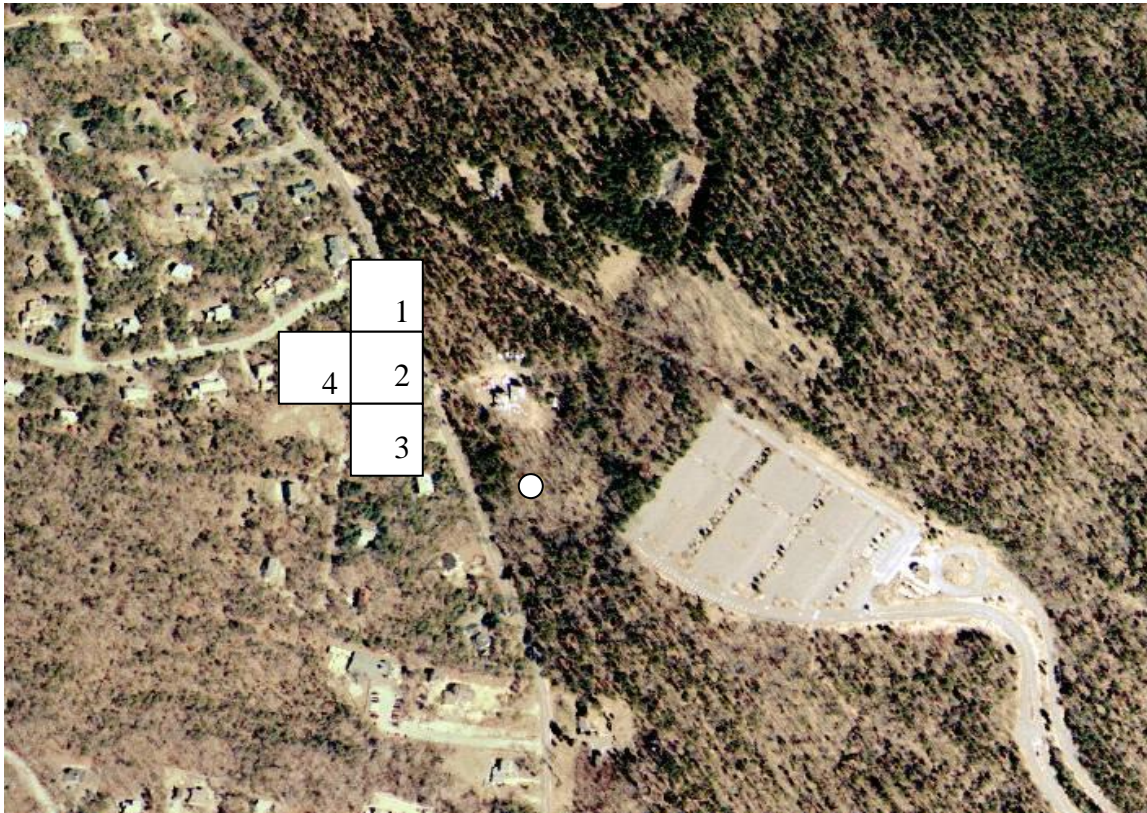
CC39

Directions: From NACL, take Route 6 east toward Provincetown. Take a right onto Race Point Road at the set of lights on Route 6 in Provincetown. Take a left into the Beech Forest parking lot. Park here. Walk on the trail until there is sand dune on the right-hand side. Hike up the dune and walk along this ridge on a footpath. The site is at the top of the hill

Modules: Four square. N–S bearing for modules = 0º, Canopy photos from center
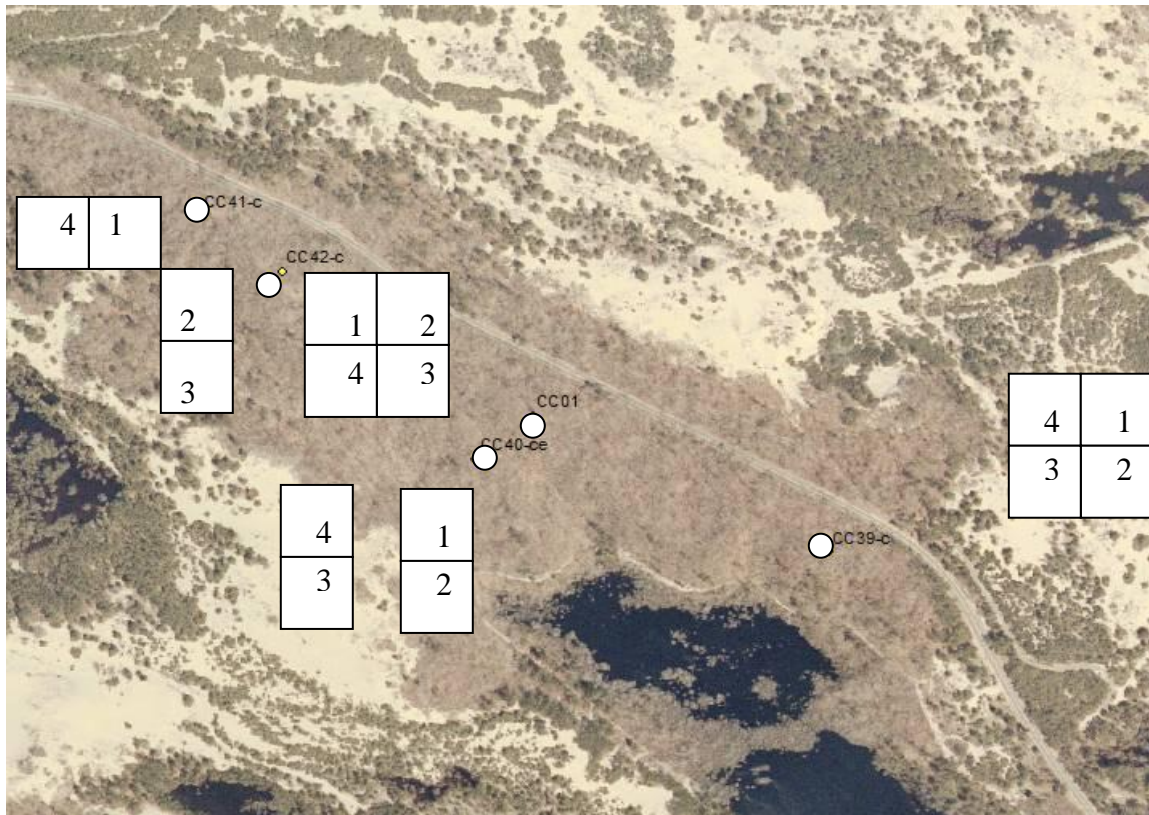
CC40

Directions: From NACL, take Route 6 east toward Provincetown. Take a right onto Race Point Road at the set of lights on Route 6 in Provincetown. Take a left into the Beech Forest parking lot. Park here. Walk on the trail and keep right at the Y in the trail. Walk 200 feet. The plot is up-slope from this point.

Modules: Canopy photos from center of boundary between 1,2 and 3,4 (see Figure for CC39).

CC41

Directions: From NACL, take Route 6 east toward Provincetown. Take a right onto Race Point Road at the set of lights on Route 6 in Provincetown. Drive until the Provincelands Visitor Center on the right side of the road. Turn around in this parking lot and drive back down Race Point Road in the opposite direction. Park at the first pull-off on the right side of the road.

Modules: N–S axis = 30° Canopy photos from center of boundary between 1,4 and 2,3 (see Figure for CC39).

CC42

Directions: From NACL, take Route 6 east toward Provincetown. Take a right onto Race Point Road at the set of lights on Route 6 in Provincetown. Drive until the Provincelands Visitor Center on the right side of the road. Turn around in this parking lot and drive back down Race Point Road in the opposite direction. Park at the first pull-off on the right side of the road.

Modules: Four square. N–S bearing for modules = 0º, Canopy photos from center (see Figure for CC39).

Appendix C. Selected variables from 2002–2003 fixed-area plot sampling.

Mean DBH and total tree densities exhibited large site to site variance, ranging between 4.0 (CC11; Pine-Heath) and 24.7 cm (CC29; Atlantic White Cedar) for the former and between 7 trees/site (CC11; Pine-Heath) and 168 trees/site (400 m^2) (CC37; Black Locust) for the latter (Figures C1, C2). Total tree Basal Area also showed large variation, although the spatial pattern was slightly different with CC29 (Atlantic White Cedar) having the highest values for this parameter (Figure C3).
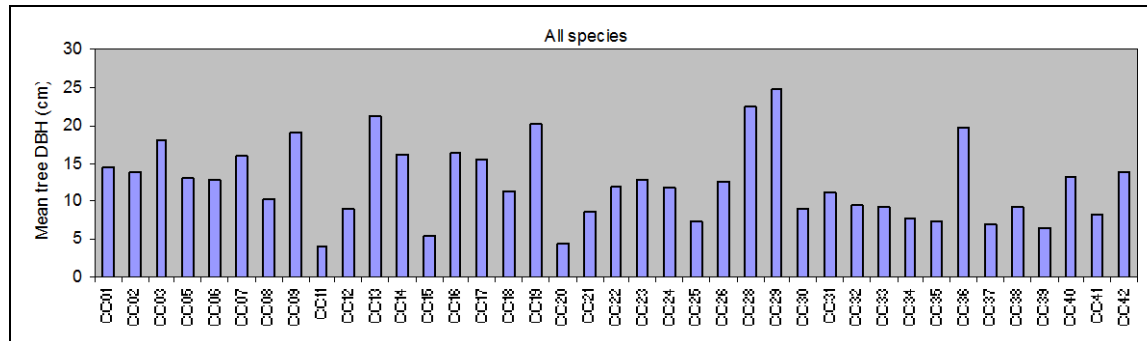
Figure C1. Mean tree DBH (all species pooled) by site.
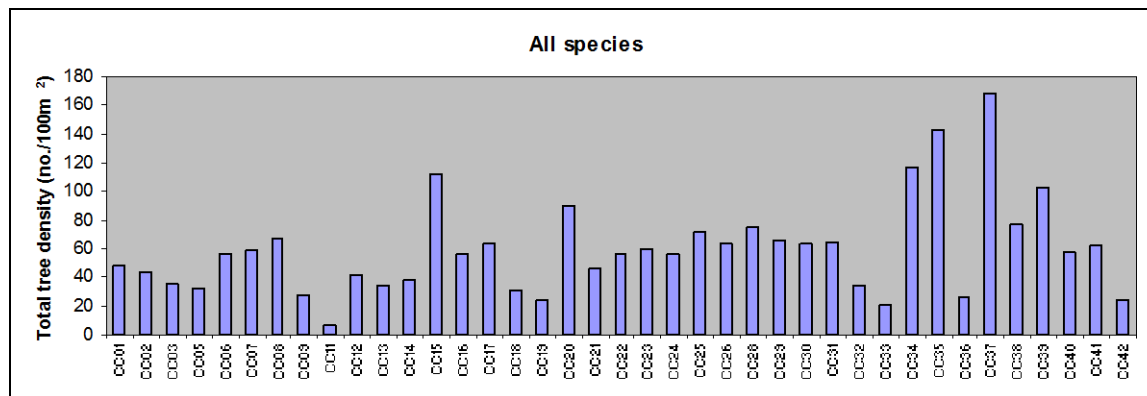
Figure C2. Total tree densities (all species pooled) by site.
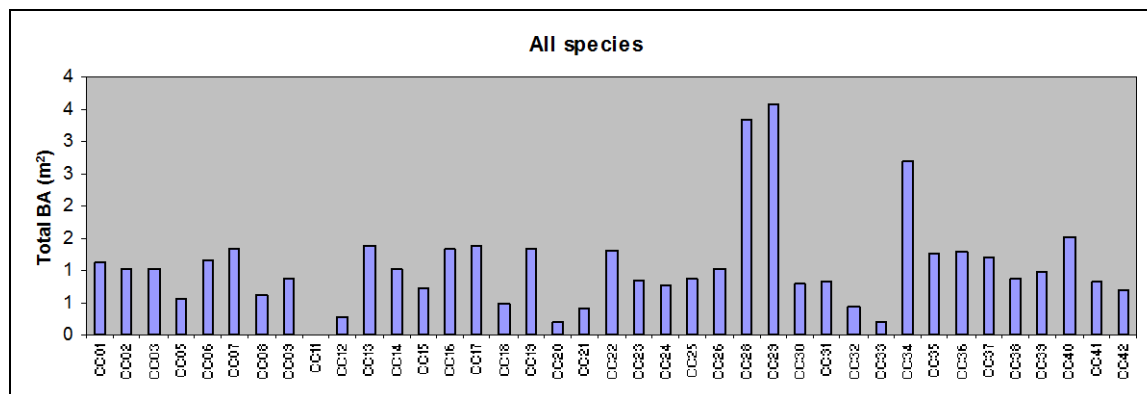
Figure C3. Total BA (all species pooled) by site).

Mean DBH by individual tree species (all sites pooled) was highly variable, ranging between 4.1 cm for *Amelachier* spp. and 25.6 cm for *Chamaecyparis thyoides* (Figure C4). The variance was highly dependent upon population demographics. For example, numerous young trees (saplings) exist in the black and white oak forest, which lowers mean DBH values, whereas there are only large, old individuals of *C. thyoides* in the Atlantic White Cedar sites. Tree densities by species ranged between 43 for *Nyssa sylvatica* and 552 for *P. rigida* (Figure C5). Total BA by species (all sites pooled) ranged between 0.16 m/m^2 for *Amelanchier* spp. and 13.47 m/m^2 for *P. rigida* (Figure C6). Although *C. thyoides* is present at only two sites, BA values are comparatively high, mainly due to the large tree size m/m^2, at these sites.
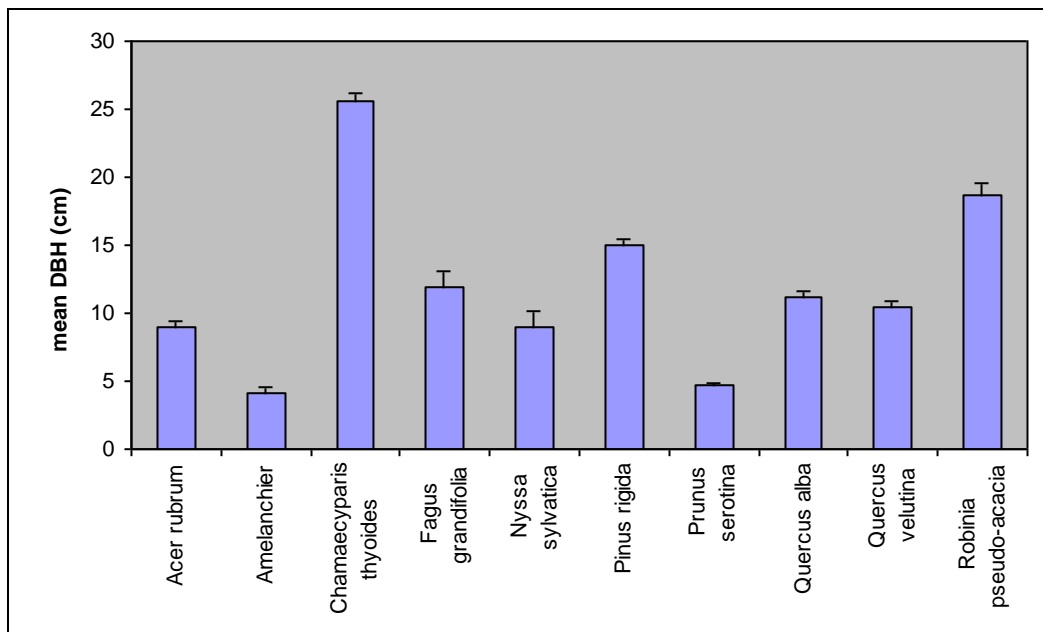
Figure C4. Mean diameter at breast height (DBH) by species (all sites).
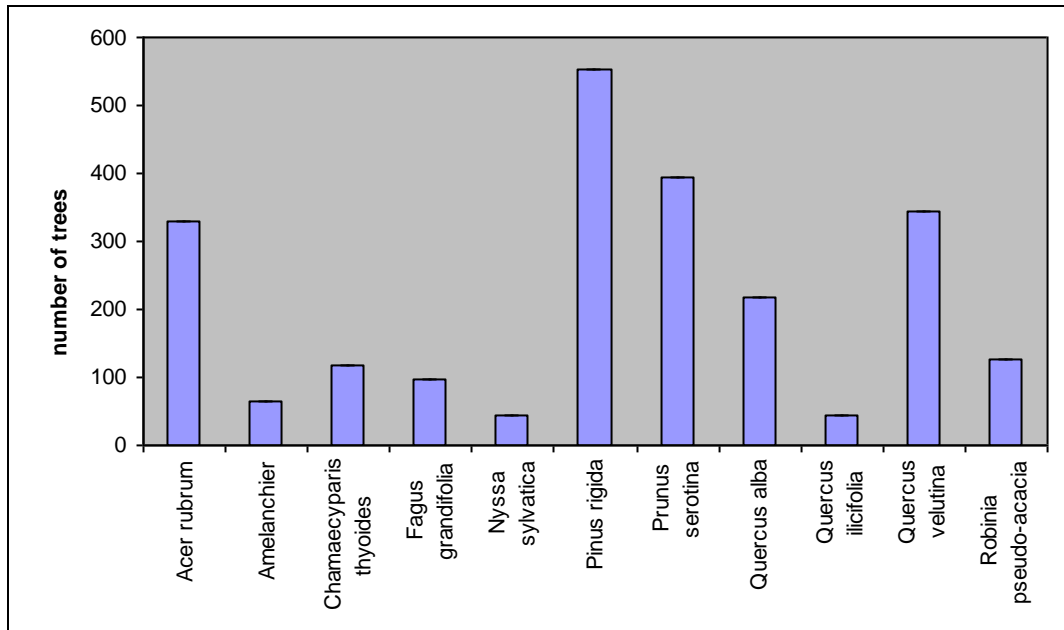
Figure C5. Total number of trees by species (all sites).
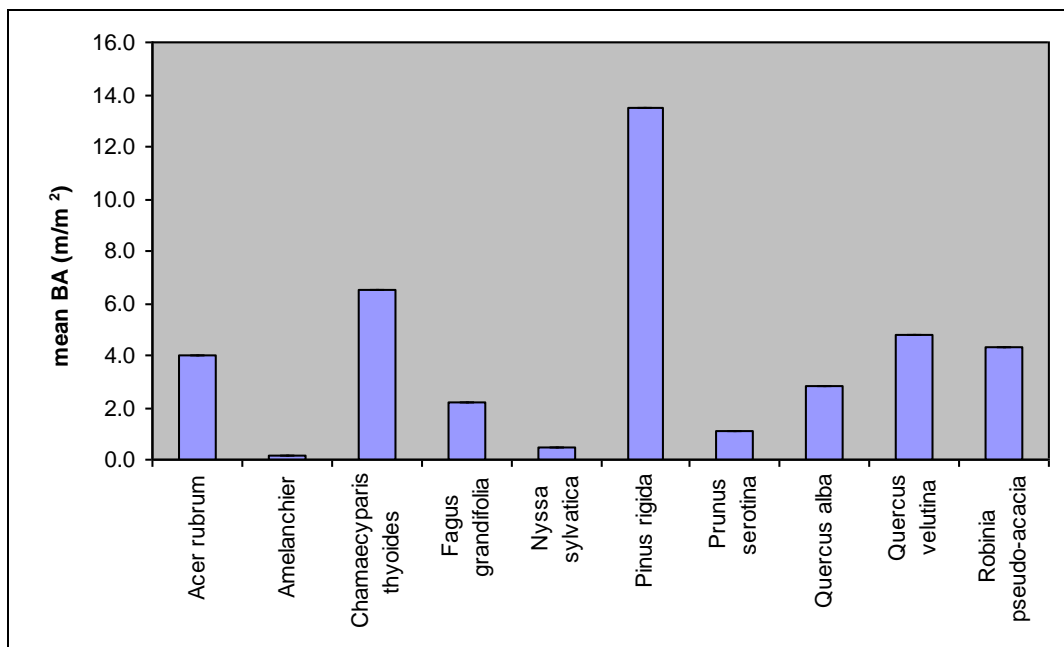
Figure C6. Total Basal Area (BA) by species (all sites).

Overstory tree diversity was lowest at CC11 (Pine-Heath) and highest at CC38 (Black Locust) with total species numbers of 1 and 5, respectively (Figure C7).
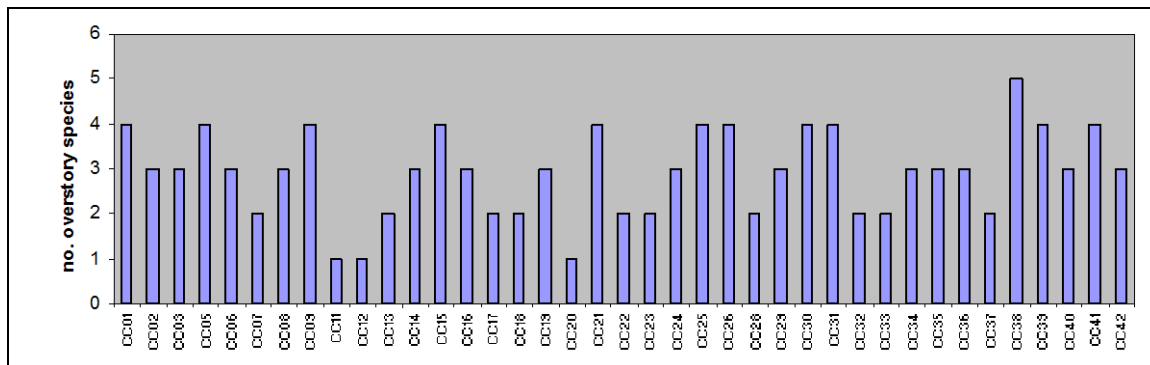
Figure C7. Number of overstory species by site.

Data collected from the fixed-area plots during 2002–2003 were subjected to cluster analysis (Primer™) as a way to assess current compositional variability among sites and whether the habitat type designations (i.e., red maple, pine-oak) manifested themselves as statistically related groups. In general, sites designated as a particular forest type clustered together reasonably well based on basal area and tree densities (Figures C8 and C9).
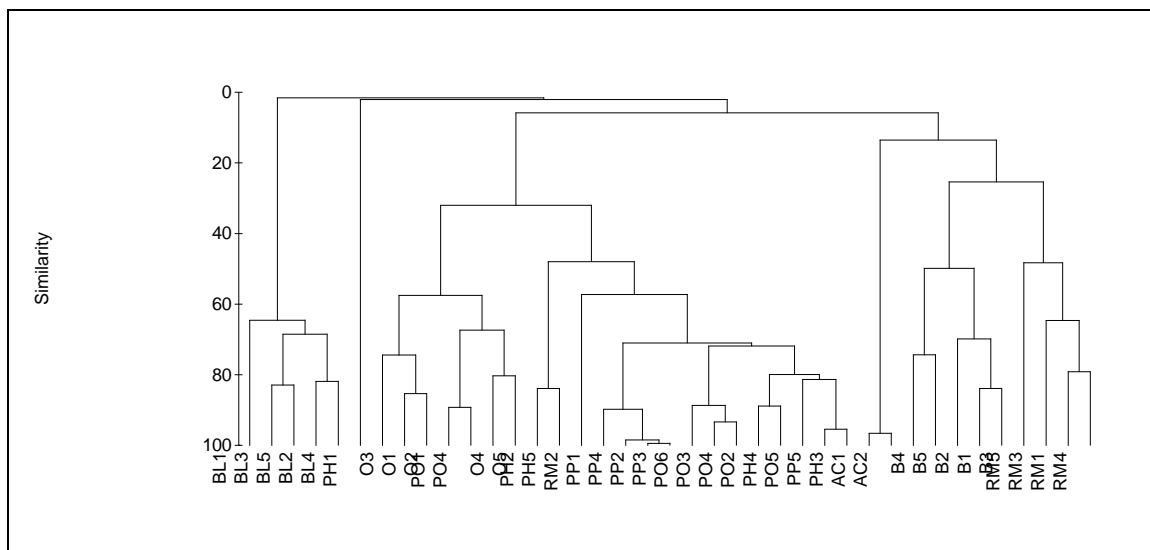
Figure C8. Cluster analysis based on tree basal area (BL=Black Locust, O=Black and White Oak, PP=Pitch Pine, PH=Pine-Heath, B=Beech, RM=Red Maple, AC=Atlantic White Cedar).
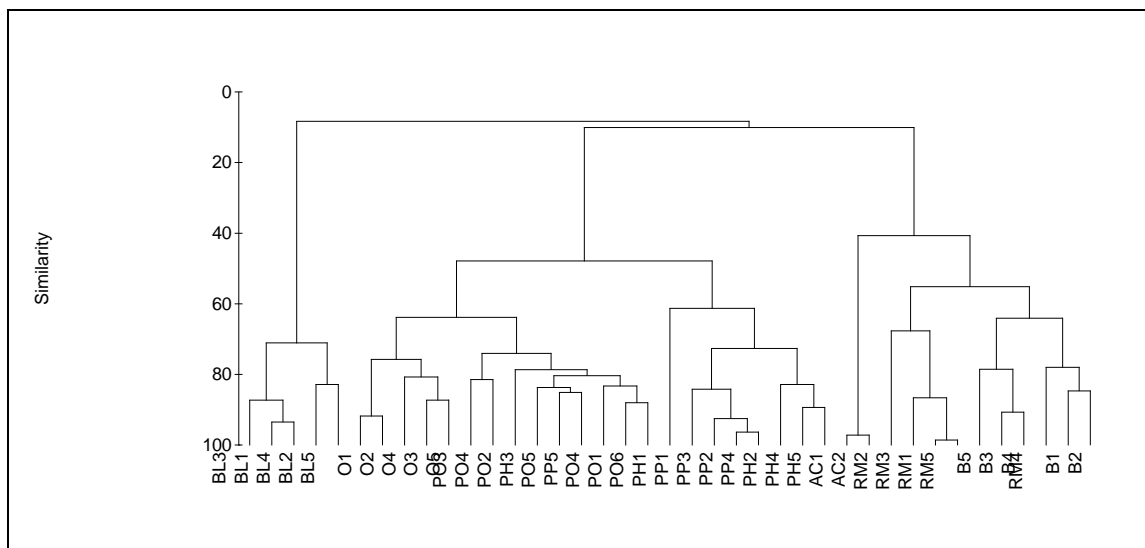
Figure C9. Cluster analysis based on tree densities (BL=Black Locust, O=Black and White Oak, PP=Pitch Pine, PH=Pine-Heath, B=Beech, RM=Red Maple, AC=Atlantic White Cedar)

Multidimensional scaling using Bray–Curtis similarity matrices (generated in Primer™) based on near-ground cover data indicated that sites showed substantial scattering with few tight groupings (Figure C10). Ground cover exhibited considerably higher similarity among sites with a greater degree of overlap and distinct clusters. no mention of figure C11 or table C1 here?
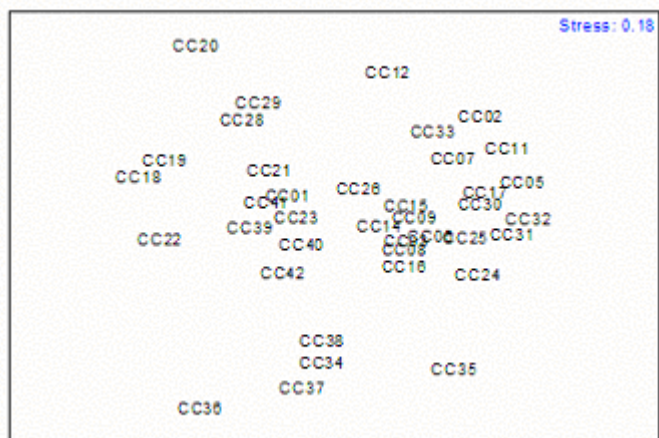
Figure C10. Multidimensional scaling depicting similarity among sites based on near-ground cover (log-transformed mid points of cover classes).
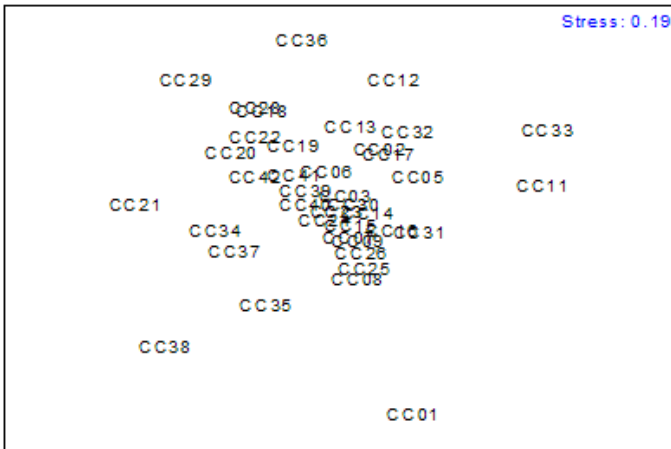
Figure C11. Multidimensional scaling depicting similarity among sites based on ground cover (log-transformed mid points of cover classes).

Table C1. Near-ground and ground layer species recorded in 2000–2003

Near-ground layer	Ground layer
Acer rubrum	*Acer rubrum*
Amelanchier	*Amelanchier*
Amelanchier sp.	*Amelanchier sp.*
Aralia nudicaulis	*Aralia nudicaulis*
Berberis vulgaris	*Arctostaphylos uva-ursi*
Boehmeria cylindrica	*Carex lacustris*
Carex lacustris	*Carex pensylvanica*
Chamaecyparis thyoides	*Chamaecyparis thyoides*
Clethra alnifolia	*Chelidonium majus*
Comptonia peregrina	*Chimaphila maculata*
Daucus carota	*Clethra alnifolia*
Dennstaedtia punctilobula	*Comptonia peregrina*
Deschampsia flexuosa	*Corema conradii*
Euonymus atropurpurea	*Cypripedium acaule*
Fagus grandifolia	*Daucus carota*
Gaylussacia baccata	*Dennstaedtia punctilobula*
Holcus lanatus	*Deschampsia flexuosa*
Ilex glabra	*Epigaea repens*
Ilex opaca	*Fagus grandifolia*
Juncus	*Fragaria virginiana*
Juniperus communis	*Gaultheria procumbens*
Kalmia angustifolia	*Gaylussacia baccata*
Leonurus cardiaca	*Holcus lanatus*
Lepidium campestre	*Hudsonia ericoides*
Lonicera japonica	*Hudsonia tomentosa*
Lonicera morrowii	*Ilex glabra*
Lysimachia terrestris	*Ilex opaca*
Mentha arvensis	*Kalmia angustifolia*
Myrica pensylvanica	*Leonurus cardiaca*
Nyssa sylvatica	*Lichen sp.*
Onoclea sensibilis	*Lonicera japonica*

Near-ground layer	Ground layer
Osmunda cinnamomea	*Lonicera morrowii*
Panicum	*Maianthemum canadense*
Parthenocissus quinquefolia	*Melampyrum lineare var. lineare*
Pinus rigida	*Mentha arvensis*
Polygonum scandens var. scandens	*Mitchella repens*
Populus tremuloides	*Moss sp.*
Prunus serotina	*Myrica pensylvanica*
Pteridium aquilinum	*Nyssa sylvatica*
Quercus	*Onoclea sensibilis*
Quercus alba	*Osmunda cinnamomea*
Quercus ilicifolia	*Oxalis stricta*
Quercus velutina	*Panicum*
Rhamnus cathartica	*Parthenocissus quinquefolia*
Rhododendron viscosum	*Pinus rigida*
Robinia pseudo-acacia	*Polygonella articulata*
Rosa carolina	*Polygonum scandens var. scandens*
Rosa palustris	*Prenanthes trifoliata*
Rosa virginiana	*Prunus serotina*
Rubus allegheniensis	*Pteridium aquilinum*
Rubus flagellaris	*Quercus alba*
Rumex crispus	*Quercus ilicifolia*
Sassafras albidum	*Quercus velutina*
Sisymbrium officinale	*Rhododendron viscosum*
Smilax rotendifolia	*Ribes hirtellum*
Smilax rotundifolia	*Robinia pseudo-acacia*
Solanum dulcamara	*Rosa carolina*
Solidago rugosa	*Rosa palustris*
Spiraea alba	*Rosa virginiana*
Toxicodendron radicans	*Rubus allegheniensis*
Toxicodendron vernix	*Rubus flagellaris*
Typha latifolia	*Sassafras albidum*
Vaccinium angustifolium	*Schizachyrium scoparium*
Vaccinium corymbosum	*Scirpus cyperinus*
Viburnum cassinoides	*Sisymbrium officinale*
Viburnum dentatum	*Smilax rotundifolia*
Vitis labrusca	*Solanum dulcamara*
Woodwardia areolata	*Solidago canadensis*
	Solidago rugosa
	Spiraea alba
	Toxicodendron radicans
	Toxicodendron vernix
	Trientalis borealis
	Vaccinium angustifolium
	Vaccinium corymbosum
	Vaccinium macrocarpon
	Viburnum cassinoides
	Viburnum dentatum
	Vitis labrusca
	Woodwardia areolata

Appendix D. Summary of selected power analyses.

Power to detect change in all trees (all species pooled) across entire network (all sites pooled).

	Parameter	Transf	Power (±20%)	Power (±50%)
All trees	DBH	log	95%	100%
All trees	BA	log	56/71%	100%
All trees	Density	log	53/99%	100%

Power to detect change in a single species across entire network (all sites pooled)

Species	Parameter	Transf	Power (±20%)	Power (±50%)
Acer rubrum	DBH	log	100%	100%
Amelanchier spp.	DBH	log	28%	89%
Chamaecyparis thyoides	DBH	log	100%	100%
Fagus grandifolia	DBH	log	64%	100%
Nyssa sylvatica	DBH	log	72%	100%
Pinus rigida	DBH	log	100%	100%
Prunus serotina	DBH	log	100%	100%
Quercus alba	DBH	log	100%	100%
Quercus velutina	DBH	log	100%	100%
Robinia pseudo-acacia	DBH	log	100%	100%

Power to detect change in mean tree DBH (all species pooled) at each site.

Site	Parameter	Transf	Power (±20%)	Power (±50%)
CC01	DBH	log	91%	100%
CC02	DBH	log	71%	100%
CC03	DBH	log	100%	100%
CC05	DBH	log	81%	100%
CC06	DBH	log	77%	100%
CC07	DBH	log	100%	100%
CC08	DBH	log	100%	100%
CC09	DBH	log	100%	100%
CC11	DBH	log	60%	99%
CC12	DBH	log	100%	100%
CC13	DBH	log	100%	100%
CC14	DBH	log	87%	100%
CC15	DBH	log	50%	99%
CC16	DBH	log	100%	100%
CC17	DBH	log	100%	100%
CC18	DBH	log	70%	100%
CC19	DBH	log	57%	100%
CC20	DBH	log	68%	100%
CC21	DBH	log	50%	99%
CC22	DBH	log	87%	100%
CC23	DBH	log	100%	100%

Site	Parameter	Transf	Power (±20%)	Power (±50%)
CC24	DBH	log	93%	100%
CC25	DBH	log	35%	94%
CC26	DBH	log	88%	100%
CC28	DBH	log	100%	100%
CC29	DBH	log	100%	100%
CC30	DBH	log	47%	99%
CC31	DBH	log	96%	100%
CC32	DBH	log	46%	98%
CC33	DBH	log	39%	95%
CC34	DBH	log	59%	100%
CC35	DBH	log	71%	100%
CC36	DBH	log	60%	100%
CC37	DBH	log	97%	100%
CC38	DBH	log	63%	100%
CC39	DBH	log	44%	99%
CC40	DBH	log	66%	100%
CC41	DBH	log	29%	89%
CC42	DBH	log	31%	88%

Power to detect change in mean tree BA (based on averages of module BA values; all species pooled) at each site.

Site	Parameter	Transf	Power (±20%)	Power (±50%)
CC01	BA	log	99%	100%
CC02	BA	log	99%	100%
CC03	BA	log	99%	100%
CC05	BA	log	16%	58%
CC06	BA	log	99%	100%
CC07	BA	log	99%	100%
CC08	BA	log	99%	100%
CC09	BA	log	99%	100%
CC11	BA	log	8%	15%
CC12	BA	log	8%	14%
CC13	BA	log	99%	100%
CC14	BA	log	99%	100%
CC15	BA	log	99%	100%
CC16	BA	log	99%	100%
CC17	BA	log	99%	100%
CC18	BA	log	26%	86%
CC19	BA	log	16%	58%
CC20	BA	log	96%	100%
CC21	BA	log	23%	82%
CC22	BA	log	44%	98%
CC23	BA	log	88%	100%
CC24	BA	log	84%	100%
CC25	BA	log	19%	69%
CC26	BA	log	100%	100%
CC28	BA	log	100%	100%

Site	Parameter	Transf	Power (±20%)	Power (±50%)
CC29	BA	log	100%	100%
CC30	BA	log	81%	100%
CC31	BA	log	32%	93%
CC32	BA	log	14%	50%
CC33	BA	log	97%	100%
CC34	BA	log	100%	100%
CC35	BA	log	100%	100%
CC36	BA	log	18%	65%
CC37	BA	log	89%	100%
CC38	BA	log	99%	100%
CC39	BA	log	99%	100%
CC40	BA	log	99%	100%
CC41	BA	log	92%	100%
CC42	BA	log	34%	95%

Power to detect change in a single species at each site (shaded sites indicate forest types corresponding to the species being tested).

Site	Species	Parameter	Transf	Power (±20%)	Power (±50%)
CC02	*P. rigida*	DBH	log	78%	100%
CC03	*P. rigida*	DBH	log	100%	100%
CC05	*P. rigida*	DBH	log	99%	100%
CC06	*P. rigida*	DBH	log	100%	100%
CC07	*P. rigida*	DBH	log	100%	100%
CC09	*P. rigida*	DBH	log	100%	100%
CC11	*P. rigida*	DBH	log	67%	100%
CC12	*P. rigida*	DBH	log	100%	100%
CC13	*P. rigida*	DBH	log	100%	100%
CC14	*P. rigida*	DBH	log	100%	100%
CC15	*P. rigida*	DBH	log	33%	92%
CC16	*P. rigida*	DBH	log	100%	100%
CC17	*P. rigida*	DBH	log	100%	100%
CC19	*P. rigida*	DBH	log	78%	100%
CC24	*P. rigida*	DBH	log	7%	11%
CC25	*P. rigida*	DBH	log	24%	92%
CC26	*P. rigida*	DBH	log	100%	100%
CC30	*P. rigida*	DBH	log	100%	100%
CC31	*P. rigida*	DBH	log	100%	100%
CC32	*P. rigida*	DBH	log	42%	98%
CC33	*P. rigida*	DBH	log	48%	99%
CC03	*Q. alba*	DBH	log	96%	100%
CC05	*Q. alba*	DBH	log	16%	60%
CC08	*Q. alba*	DBH	log	95%	100%
CC09	*Q. alba*	DBH	log	100%	100%
CC15	*Q. alba*	DBH	log	38%	95%
CC16	*Q. alba*	DBH	log	95%	100%
CC23	*Q. alba*	DBH	log	100%	100%
CC24	*Q. alba*	DBH	log	97%	100%

Site	Species	Parameter	Transf	Power (±20%)	Power (±50%)
CC25	*Q. alba*	DBH	log	43%	98%
CC26	*Q. alba*	DBH	log	75%	100%
CC30	*Q. alba*	DBH	log	8%	15%
CC31	*Q. alba*	DBH	log	23%	90%
CC01	*Q. velutina*	DBH	log	100%	100%
CC02	*Q. velutina*	DBH	log	12%	60%
CC03	*Q. velutina*	DBH	log	100%	100%
CC05	*Q. velutina*	DBH	log	5%	6%
CC06	*Q. velutina*	DBH	log	77%	100%
CC07	*Q. velutina*	DBH	log	5%	7%
CC08	*Q. velutina*	DBH	log	100%	100%
CC09	*Q. velutina*	DBH	log	100%	100%
CC13	*Q. velutina*	DBH	log	5%	6%
CC14	*Q. velutina*	DBH	log	56%	100%
CC15	*Q. velutina*	DBH	log	26%	89%
CC16	*Q. velutina*	DBH	log	100%	100%
CC17	*Q. velutina*	DBH	log	5%	5%
CC21	*Q. velutina*	DBH	log	6%	11%
CC23	*Q. velutina*	DBH	log	100%	100%
CC24	*Q. velutina*	DBH	log	31%	100%
CC25	*Q. velutina*	DBH	log	8%	23%
CC26	*Q. velutina*	DBH	log	19%	81%
CC30	*Q. velutina*	DBH	log	24%	87%
CC31	*Q. velutina*	DBH	log	18%	80%
CC35	*Q. velutina*	DBH	log	63%	100%
CC38	*Q. velutina*	DBH	log	5%	5%
CC39	*Q. velutina*	DBH	log	96%	100%
CC40	*Q. velutina*	DBH	log	60%	99%
CC01	*A. rubrum*	DBH	log	94%	100%
CC18	*A. rubrum*	DBH	log	65%	100%
CC19	*A. rubrum*	DBH	log	50%	99%
CC20	*A. rubrum*	DBH	log	68%	100%
CC21	*A. rubrum*	DBH	log	65%	100%
CC22	*A. rubrum*	DBH	log	76%	100%
CC28	*A. rubrum*	DBH	log	22%	72%
CC29	*A. rubrum*	DBH	log	23%	75%
CC39	*A. rubrum*	DBH	log	27%	80%
CC40	*A. rubrum*	DBH	log	33%	92%
CC41	*A. rubrum*	DBH	log	15%	46%
CC42	*A. rubrum*	DBH	log	20%	69%
CC21	*R. pseudo-acacia*	DBH	log	-	-
CC34	*R. pseudo-acacia*	DBH	log	99%	100%
CC35	*R. pseudo-acacia*	DBH	log	74%	100%
CC36	*R. pseudo-acacia*	DBH	log	62%	100%
CC37	*R. pseudo-acacia*	DBH	log	68%	100%
CC38	*R. pseudo-acacia*	DBH	log	100%	100%
CC28	*C. thyoides*	DBH	log	100%	100%
CC29	*C. thyoides*	DBH	log	100%	100%
CC01	*F. grandifolia*	DBH	log	38%	97%
CC39	*F. grandifolia*	DBH	log	5%	7%

Site	Species	Parameter	Transf	Power (±20%)	Power (±50%)
CC40	*F. grandifolia*	DBH	log	46%	99%
CC41	*F. grandifolia*	DBH	log	20%	66%
CC42	*F. grandifolia*	DBH	log	18%	59%
CC18	*N. sylvatica*	DBH	log	9%	31%
CC19	*N. sylvatica*	DBH	log	24%	79%
CC22	*N. sylvatica*	DBH	log	79%	100%
CC41	*N. sylvatica*	DBH	log	13%	43%
CC42	*N. sylvatica*	DBH	log	-	-
CC14	*P. serotina*	DBH	log	9%	20%
CC34	*P. serotina*	DBH	log	34%	96%
CC35	*P. serotina*	DBH	log	62%	100%
CC36	*P. serotina*	DBH	log	21%	80%
CC37	*P. serotina*	DBH	log	96%	100%
CC38	*P. serotina*	DBH	log	45%	98%

Power to detect change in the Shannon-Weiner diversity of overstory vegetation across all sites (all sites pooled).

Parameter	Transf	Power (±20%)	Power (±50%)
S-W Diversity (BA)	none necessary	32%	90%
S-W Diversity (density)	none necessary	42%	93%

Power to detect change in the Shannon-Weiner diversity of near-ground layer vegetation across all sites (all sites pooled).

Parameter	Transf	Power (±20%)	Power (±50%)
S-W Diversity (cover)	none necessary	99%	100%

Power to detect change in the Shannon-Weiner diversity of near-ground layer vegetation across all sites (all sites pooled).

Parameter	Transf	Power (±20%)	Power (±50%)
S-W Diversity (cover)	none necessary	100%	100%

Appendix E. Field forms.

1. Ground and near-ground layer taxonomic composition.

Site:	Date:																Collectors:	Entered:		Proofed:		Comments

Ground (<0.5m) (1m2 plots)	I NE	I NW	I SW	I SE	II NE	II NW	II SW	II SE	III NE	III NW	III SW	III SE	IV NE	IV NW	IV SW	IV SE	
Near ground (>0.5-<2m) (10m2 plots)	I NE	I NW	I SW	I SE	II NE	II NW	II SW	II SE	III NE	III NW	III SW	III SE	IV NE	IV NW	IV SW	IV SE	

+ is species present in module, but not in nested plot
Herb measured 1m square only
Shrub measured 3.3m square
Cover Class (%):   **1**=trace; **2**=0-1; **3**=1-2; **4**=2-5; **5**=5-10
                6=10-25; **7**=25-50; **8**=50-75; **9**=75-100

2. Tree size and condition.

Tag No.	Site	Module	Tree Species	DBH	Health category	Height of tallest tree in Module (m)	Comments

Date Collected: _____

Collectors: _____

Data Entered: _____ Proofed: _____

3. Tree seedling densities.

Tree seedling counts				
Collected by:			Date Entered:	
Date:			Date Proofed:	
Site	Module	Species	Count	Total

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